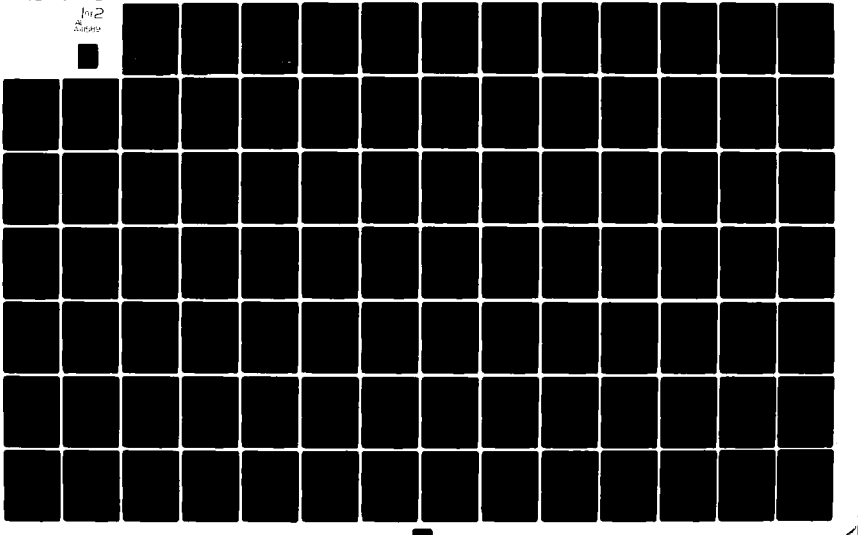
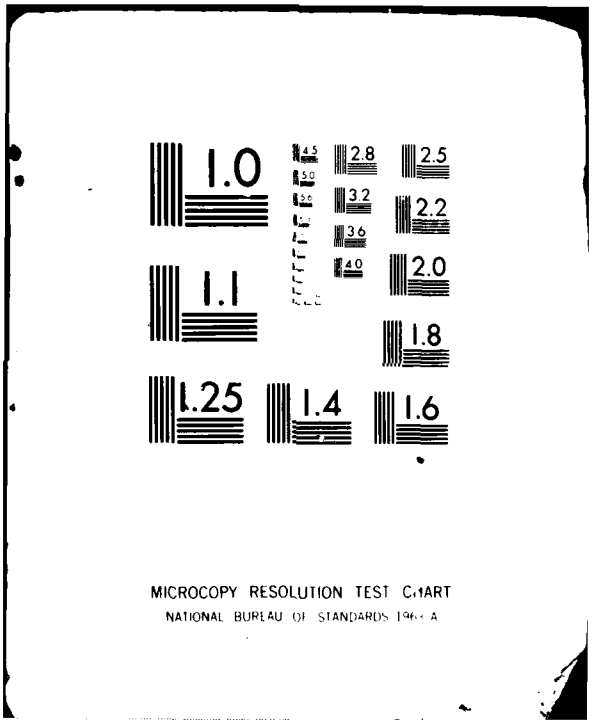
AD-A111 509 GENERAL ACCOUNTING OFFICE WASHINGTON DC COMMUNITY AN--ETC F/G 9/2
PROBLEMS PLAGUE NATIONAL WEATHER SERVICE ADP SYSTEM.(U)
NOV 81
UNCLASSIFIED GAO/CED-82-6 NL




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

BY THE COMPTROLLER GENERAL

# Report To The Congress

OF THE UNITED STATES

# Problems Plague National Weather Service ADP System

Poor project management and severe technical problems have hindered National Weather Service efforts to develop its Automation of Field Operations and Services system. AFOS is at least 5 years behind schedule, has cost $100 million--about $22 million over its original budget--and cannot meet its original requirements.

To overcome AFOS' deficiencies, the Service plans to design and develop a new system that should meet all original requirements. It also plans to operate AFOS "as is" while the new system is under development.

GAO is recommending that the Service reappraise AFOS and subject it to further testing. In addition, the Service should prepare a comprehensive plan, including a cost-benefit analysis, before implementing AFOS nationwide. Because AFOS, if implemented, would be an interim system, the Service should immediately commit resources to developing a replacement system.





UNITED STATES GENERAL ACCOUNTING OFFICE

CED-82-6
NOVEMBER 18, 1981

Request for copies of GAO reports should be sent to:

U.S. General Accounting Office
Document Handling and Information
Services Facility
P.O. Box 6015
Gaithersburg, Md. 20760

Telephone (202) 275-6241

The first five copies of individual reports are free of charge. Additional copies of bound audit reports are $3.25 each. Additional copies of unbound report (i.e., letter reports) and most other publications are $1.00 each. There will be a 25% discount on all orders for 100 or more copies mailed to a single address. Sales orders must be prepaid on a cash, check, or money order basis. Check should be made out to the "Superintendent of Documents".

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON D.C. 20548

B-205158

To the President of the Senate and the
Speaker of the House of Representatives

This report describes major design problems and management deficiencies with the National Weather Service's Automation of Field Operations and Services (AFOS) project. We conclude that before NWS can proceed with national implementation it should complete a full economic assessment and thorough testing of all aspects of the system to determine whether national implementation is cost effective.

We support the Service's plan to develop a new system to replace AFOS, but the Service has not adequately addressed the impact of a new systems development effort on its capacity to run AFOS and the current communications system.

This review was undertaken in response to an April 11, 1980, request by Congressman Willis D. Gradison, Jr. At his request we examined the AFOS project's justification, technical adequacy, and management.

We are sending copies of this report to the Director, Office of Management and Budget; the Administrator, General Services Administration; and other interested parties and will make copies available to the public upon request.

Charles A. Bowsher

Comptroller General
of the United States

COMPTROLLER GENERAL'S
REPORT TO THE CONGRESS

# PROBLEMS PLAGUE NATIONAL WEATHER SERVICE ADP SYSTEM

## D I G E S T

The National Weather Service should halt implementation of its automated data processing and telecommunications system until it more completely resolves the system's problems and clearly establishes that the benefits of full operation are worth the substantial costs. The system is called Automation of Field Operations and Services (AFOS). Problems and recommendations are discussed.

GAO conducted this review at the request of Congressman Willis D. Gradison, Jr., who was concerned that implementing the system might not be practical or feasible.

## OVERVIEW OF SYSTEM PROBLEMS AND GAO's RECOMMENDATIONS

After 7 years of development and expenditures of $100 million, the National Weather Service has implemented AFOS in two of its four principal regions. GAO's evaluation of the system found substantial problems in its design, operation, maintenance, and management. GAO found, in addition, that several of the design problems are inherent in the system and cannot be resolved short of a complete redesign.

Because of system limitations, the Weather Service had to freeze the development of AFOS--before functions initially planned could be added. As a result, AFOS is not capable, for example, of transmitting radar imagery data to field offices from the radar systems currently being built. Also, it cannot transmit satellite imagery data to local field offices. To perform these and other added functions, the Weather Service is designing a totally new system which it expects to have in service by 1989 or 1990.

Despite the limitations of AFOS, the Weather Service plans to complete national implementation and to use AFOS on an "as is" basis from 1982 to 1990. GAO recommends that the Weather Service proceed with national implementation only if (1) thorough testing of all critical aspects of the system indicates that full operations are feasible and (2) the Weather Service undertakes

a cost/benefit analysis concluding that full implementation is cost effective. (See ch. 7.)

GAO also recommends that the Weather Service:

--Establish an overall project management office and assign personnel to it, including a project manager, on a full-time basis both for completing AFOS and for developing any new system.

--Adhere to standard software development practices in completing AFOS and in developing any new system. (See ch. 4.)

--Replace completely all AFOS software, hardware, and telecommunications in developing any new system.

--Contract out system development activities when they exceed in-house capabilities.

--Account for all costs, including the full personnel costs attributable to using AFOS and developing a new system. (See ch. 2.)

Unless the Weather Service resolves these management weaknesses and technical problems, GAO believes that AFOS and the effort to develop a new system face continued difficulties and a risk of total failure.

SPECIFIC PROBLEMS

Originally planned to be completed by 1979, AFOS is currently not scheduled to operate until 1984 without backup from the system it replaces. Cost overruns approximating $22 million have been incurred in the development phase. Expected cost savings from automation have not yet been generated. (See ch. 2.)

Delay and excess costs are the result of the following problems:

--AFOS hardware lacks sufficient core memory to accommodate current software or applications initially planned for AFOS; the Weather Service cannot tell how much more memory is needed.

--AFOS computer's operating system cannot meet concurrent processing requirements originally specified.

--Software subsystems are integrated to the extent that modifications to one software segment may result in problems with other segments. (See ch. 4.)

--Development of the software and changes made along the way are not sufficiently documented, making further development of AFOS difficult and expensive.

--Reliability of a fully operational AFOS has yet to be shown. (See ch. 7.)

--The "loop" design for AFOS telecommunications, which connects the main weather forecast offices in four continuous chains, is subject to system problems whenever difficulties are encountered in any single link. It requires more uniformity of procedures, system discipline, and centralized enforcement than has been the practice in the Weather Service. (See ch. 5.)

--AFOS cannot receive and process information from remote meteorological observing locations.

--The Weather Service has removed some of the system's backup capabilities to stabilize and simplify current operations.

--Some AFOS hardware is already obsolete and maintenance is expensive because unavailable spare parts have to be specially made. (See ch. 6.)

--AFOS hardware--computers and spare parts--was procured prematurely and was not updated as new technology was made available by the vendor. (See ch. 6.)

## OPTIONS FOR FUTURE OPERATIONS AND COSTS

The Weather Service is currently proceeding with national implementation of AFOS, which it expects to complete before the end of 1982. At the same time it plans to maintain the system AFOS replaces, an FAA-owned set of teletype networks, for backup purposes, at least until 1984. GAO believes that operating these two systems in parallel for 3 more years is an unusually long trial period for AFOS. Yet, the Weather Service believes it needs the added security in the event

AFOS fails. Operating AFOS on this basis will cost an estimated $144 million over the 1982 to 1990 period. (See ch. 2.)

The Weather Service does not view relying solely on the existing FAA teletype system as a viable option. GAO estimates that, if AFOS were to be abandoned, it would cost the Weather Service only $28 million to continue using the FAA system over the next 8 years. The Weather Service disputes this estimate, claiming that it ignores costs for required renovations of the FAA system.

The Weather Service further states that abandoning AFOS and returning to sole reliance on the FAA teletype system would be impractical if not impossible because of shifts in operating procedures which are already in place.

GAO and the Weather Service agree that a new system, targeted for 1989 or 1990, must be developed. GAO doubts, however, that the Weather Service has the staff necessary to simultaneously operate and maintain AFOS and do the work necessary to develop the new system.

AGENCY COMMENTS AND GAO's OBSERVATIONS OF RECENT TESTS

GAO proposed in a draft version of this report provided to the agency in June 1981 that AFOS be abandoned altogether. The Weather Service disagreed and stated that it planned a validation test of AFOS in August-September 1981, to demonstrate the readiness of AFOS for national implementation. The House Appropriations Committee asked GAO to observe these tests. GAO found that some improvements have been achieved but noted that the tests did not cover all operations that AFOS is expected to perform. (See ch. 7.)

These recent improvements do not address and were not intended to resolve AFOS' basic design problems, such as (1) the potential for major malfunctions, (2) the lack of computer memory capacity, (3) the inflexibility and cost of, and the level of personnel support required by, the telecommunications system, and (4) the fact that the system cannot meet all of the Weather Service's operational requirements.

GAO still questions whether implementing AFOS is worth the cost in view of its limited functional

capabilities and operational problems. AFOS does meet some of the Weather Service's planned objectives. It will increase the information available to local weather offices, make information available much faster, and provide limited data processing capability to field offices. In light of these benefits, the recent improvements, and the expenditure of $100 million to date on AFOS, GAO at this time does not recommend outright abandonment of AFOS. However, GAO believes the burden rests with the Weather Service to show that benefits of using AFOS over the next 8 years exceed the costs, assuming that testing of all essential aspects indicates that AFOS can reliably perform its remaining functions.

# Contents

## ABBREVIATIONS

| | |
|---|---|
| ADP | automatic data processing |
| AFOS | Automation of Field Operations and Services |
| FAA | Federal Aviation Administration |
| GAO | General Accounting Office |
| NMC | National Meterological Center |
| NOAA | National Oceanic and Atmospheric Administration |
| NWS | National Weather Service |
| SMCC | System Monitoring and Coordination Center |
| WSFO | Weather Service Forecast Office |
| WSO | Weather Service Office |

# CHAPTER 1

# INTRODUCTION

## BACKGROUND

The National Weather Service (NWS) was established in 1970 as the successor agency to the United States Weather Bureau. The Weather Service has evolved to its present state over more than a century of Government weather involvement. House Joint Resolution 143, passed in February 1870, authorized the Secretary of War to take observations and warn of storms on the Nation's waterways. These responsibilities were transferred by the Act of October 1, 1890 (26 Stat. 653), to the newly created Weather Bureau, a part of the Department of Agriculture. It was transferred to the Department of Commerce by Reorganization Plan Number IV of 1940 (5 F.R. 2421 and 54 Stat. 1236) and subsequently was made a part of the National Oceanic and Atmospheric Administration (NOAA). NWS provides services through its headquarters in Silver Spring, Maryland; the National Meteorological Center (NMC) in Camp Springs, Maryland; and over 400 offices throughout the United States. Of its approximately 5,000 employees, 1,000 are in the Washington area and 4,000 are in field offices.

## MISSION

NWS is responsible for protecting public safety, health, and welfare and for promoting the comfort and convenience of the general public by providing information on meteorological and hydrological conditions. NWS is also responsible for meeting the specialized information needs of weather-sensitive segments of the economy, such as agriculture and aviation. This mission is accomplished by two types of services, basic and specialized.

Basic services include

--taking hydrological and meteorological observations, analyzing them, and preparing predictions of atmospheric, hydrologic, and marine conditions and

--disseminating observations, forecasts, warnings, and other information to the public.

The public receives most of this basic weather information through two services, the NOAA Weather Wire and the NOAA Weather Radio, and through the mass media. These services transmit weather information to the public and other users.

Specialized services in support of specific needs include:

--The Fire Weather Forecast and Warning Services Programs provide specialized forecasts, warnings, and consulting services to Federal, State, and private fire management interests.

--The Marine Weather and Oceanographic Services Programs provide for safety and increased efficiency on the Nation's waterways.

--The Agricultural Weather Service provides specialized services to help increase farm production, improve agricultural efficiency, conserve energy, and protect the environment.

--The Domestic and International Aviation Weather Programs provide information for safe and efficient flight operations.

ORGANIZATION

The National Meteorological Center is the backbone of NWS operations. Its resources include large computer systems and forecast models to process weather information. Virtually all meteorological data collected arrives at NMC where it is analyzed and processed into a variety of forecast and guidance products, such as temperature and barometric pressure charts, that are then distributed to NWS field offices, private meteorologists, the public media, and governmental offices. NMC's products cover the entire globe, and the office has been designated as the analysis and forecast arm of the World Meteorological Center, fulfilling U.S. global responsibilities as part of the international effort known as the World Weather Watch.

Other NWS offices also have national weather forecasting responsibilities. The National Severe Storms Forecast Center in Kansas City, Missouri, provides a single source for severe local storm watches. The National Hurricane Center serves the same function for hurricane watches in the Atlantic, the Caribbean, and the Gulf of Mexico, and Hurricane Warning Centers in Honolulu and San Francisco provide this service for the Pacific.

NWS is organized into six regions--four covering the contiguous United States, one covering Hawaii and the Pacific Islands, and one covering Alaska. The regions are designated as eastern, central, southern, western, Alaskan, and Pacific. The field organization in the regions is a two-tier system. At the top are 52 Weather Service Forecast Offices (WSFOs) that are responsible for a specified geographical area usually corresponding to a State boundary. They receive forecast guidance and atmospheric charts from the NMC, refine them, and prepare forecasts for their areas. In addition, most WSFOs take observations.

Each WSFO also supports from one to eight smaller suboffices called Weather Service Offices (WSOs). WSOs constitute the second tier of the field system. Each WSO is connected to a WSFO and is dependent on it for support. WSOs receive selected NMC products plus the longer range forecast products prepared by their "parent" WSFOs. Further, WSOs prepare locally adapted weather forecasts, based on those prepared by the parent WSFO, which

generally cover shorter time periods and smaller areas. There are about 235 WSOs nationwide.

River Forecast Centers are an additional category of field offices. Thirteen River Forecast Centers nationwide collect and process data and prepare forecasts of levels and flow rates along river systems, water supply potential, and warnings of flood conditions.

Relationship to other Federal agencies

The Federal Aviation Administration (FAA) and two Department of Defense services, the Navy and the Air Force, also have responsibilities for collecting and disseminating weather information in the United States and overseas. These three organizations and NWS, although different in structure and mission, are dependent on each other. The basic weather mission of each service involves collecting data, developing weather forecasts, and communicating that information to users. Each of the services relies on the others in meeting some of these functions and for providing emergency backup. The exchange of information, observations, and forecasts among all services is essential for the operation of each system.

FAA, through its network of Flight Service Stations, provides weather information to the Nation's private and commercial pilots. Flight Service Stations collect weather data throughout the United States, relay it to the other services, and disseminate forecasts prepared by NWS.

The Air Force's Air Weather Service provides weather information worldwide to U.S. military air and ground forces tailored to meet their operational and planning needs. It also shares observations and forecasts with the other services.

The Navy's Naval Oceanographic Command meets the worldwide weather needs of the U.S. fleet. Its emphasis is on weather affecting the world's oceans, but it also takes observations and prepares forecasts that are shared with the other services.

CURRENT COMMUNICATIONS SYSTEM

The communications network that links NWS offices is a vast, complex, and aging network comprised of about 19 communications systems. Some of these are operated by NWS and others are the responsibility of FAA and the Department of Defense. NWS' current effort to automate its communications and data handling, known as the Automation of Field Operations and Services (AFOS) system, was planned to result in savings by eliminating 10 of these systems.

FAA and NWS have been sharing communications systems since 1927. The three primary teletypewriter systems used by NWS for transmitting weather data between offices are owned and operated

by FAA. These systems are 20 to 40 years old. Graphic products for all the weather services are transmitted over two facsimile networks owned and operated by NWS. FAA is developing its own automated weather information system and expects to complete it by 1988. FAA intends to discontinue its current teletypewriter service once a replacement system is fully operational.

## NWS' DECISION TO DEVELOP AN ADP AND TELECOMMUNICATIONS SYSTEM

In 1973 NWS decided to develop a new communications and information processing system. The decision was based on the results of studies NWS commissioned in the late 1960's and early 1970's to determine the feasibility of introducing automatic data processing (ADP) capabilities into field forecasting offices. NWS felt that it would be expected to meet increasing demands for services but that its staff resources would not increase at the same rate. (NWS' staff level has remained stable for 13 years despite the addition of new programs.) The studies showed that a large-scale effort toward automation would be required to solve anticipated personnel shortages. Automation has the capability to free field personnel from time-consuming administrative tasks associated with the current communications system, which is not automated, thus allowing more time for professional activities, such as developing and using local weather models and historical weather analysis.

NWS also believed that the use of advancements in meteorology would be accelerated by using computer analysis and prediction models at the local level. In addition, automation promised substantial improvements in response time and in providing warnings, savings by lowering operating costs, and reduced staffing problems.

## DESCRIPTION OF AFOS

AFOS is a nationwide telecommunications network of minicomputers designed to connect most NWS offices. The system will allow each field office to send and receive information needed to meet forecasting and observation responsibilities and provide local computer processing capability. AFOS, as designed, would work as follows.

Local meteorological observations (wind, temperature, rainfall, barometric pressure, etc.) are entered into the system by NWS field offices and transmitted to the NMC. The NMC takes this raw information (the local meteorological observations) and uses computer models to prepare detailed guidance and weather projections (forecasts, maps, etc.). The NMC then sends these products over the telecommunications system to the field offices.

The local offices receive and store the NMC products for use in preparing local forecasts. The field forecaster, using both graphic and alphanumeric display terminals, prepares the local weather forecast by tailoring the NMC's general guidance and the

more specific forecasts of the WSFOs to local conditions. AFOS would permit improved analysis by overlaying graphically presented data on a display screen. This allows a forecaster to use more information and a greater number of information sources in preparing forecasts. In addition, AFOS would provide the information in a more usable form and would add the capability of local ADP processing. Local ADP processing would consist of running local weather models similar to those used at the NMC to tailor the large models to local requirements.

AFOS requires a central office responsible for assessing system status, assisting in recovery from failures, maintaining system software, and driving the system. The System Monitoring and Coordination Center (SMCC) has been established for such purposes.

The telecommunications system is designed to move information from the field to the NMC and back to the field. It is currently designed to be compatible with NWS' organizational structure. WSFOs in each of NWS' four contiguous regions are connected in a single continuous circuit and information passes in both directions around this circuit to every WSFO. This type of telecommunications design is called a loop. All four regional loops are connected at the SMCC, as is the NMC. WSOs are connected to their "parent" WSFOs by direct communication lines similar to spokes in a wheel. This type of communications design is called a star. The Alaskan and Pacific regions are connected to the SMCC by spur links.

Each WSFO has two minicomputers so that one will remain operational if the other fails. The larger WSOs will have one minicomputer. The rest of the field offices will have a terminal connected to a WSFO which will allow them to enter and receive information from the system. They will not be able to process data locally. NWS has not procured or rented the terminals for these offices and does not plan to do so until AFOS is fully operational.

The AFOS hardware configuration varies depending on the type and size of the field office in which it is installed. In addition to the computer, each field office has a control console and a number of work stations. The work stations consist of graphic and alphanumeric display terminals which look and function like TV screens. A forecaster can put maps containing weather information on the graphic screen and overlay additional maps with different types of information. Alphanumeric terminals are used for message composition, to input information into the system, and to display information.

## OBJECTIVES, SCOPE, AND METHODOLOGY

Our review was performed at the request of Congressman Willis D. Gradison, Jr., to determine the problems that have

caused delays in implementing the AFOS system. Our review included management issues such as system planning, costs and benefits, coordination with external users, management adequacy, and technical issues related to ADP system development from system design through testing. We extensively studied:

--NWS' requirements both now and in the future, and AFOS' intended impact on service to the public.

--The basis on which AFOS was justified--the use of a distributed data base management and communications system 1/ to meet NWS' needs.

--NWS' organizational structure and its impact on ADP systems development, including the role of the NWS field organization in developing and implementing AFOS.

--Management's control of the system's development and its capability to develop an ADP system.

--The system's software, with emphasis on its design, to determine if it could effectively accommodate changing needs.

--The adequacy of the telecommunications, hardware, and logistics systems.

--The validation/demonstration test plan for the AFOS August-September 1981 test.

NWS staffs worked very closely with our staff during the study. We freely exchanged information on a regular basis, including information on tentative conclusions and recommendations. This approach was encouraged by Congressman Gradison.

Our methodology took into account the operational philosophy of NWS. Because NWS has a decentralized management structure, each region developed independent management plans for AFOS operation and implementation. We addressed these differing efforts and activities by performing indepth work in two regions and limited field work in two others. This work included discussions with senior officials and forecasters at local field offices in each region and extensive onsite observations. We reviewed NWS directives on the duties of field offices and the methods by which they are carried out. In addition, we reviewed the needs of three separate groups of users within each region: WSFOs, WSOs, and River Forecast Offices. Each has different requirements and end users of its services.

---

1/NWS' distributed data base management system includes the distribution of a data base at remote locations and the use of programmable minicomputers to process data in 200 field offices.

We performed detailed work in the central and western regions where the development of AFOS is the most advanced. Our work in the remaining regions provided sufficient information to address field operations as a whole.

In addition, we performed limited work at

--the NWS Technical Training Center and Repair Depot in Kansas City, Missouri, on AFOS' logistics and training program;

--the FAA Weather Message Switching Center in Kansas City, Missouri, on NWS' current system, which is primarily run by FAA;

--the Air Weather Service at Offutt Air Force Base, Omaha, Nebraska, on NWS' backup operational support in the event of a major disaster to the NMC;

--the Ford Aerospace Communications Corporation, the contractor which assembled the AFOS hardware, in Palo Alto, California, on the performance characteristics of the AFOS system and future logistics costs and support;

--the Data General Corporation, the contractor which supplied the AFOS minicomputers, in Westboro, Massachusetts; and

--the Environmental Research Laboratory, the primary source of research for U.S. meteorological services, in Boulder, Colorado, on new techniques and services that would need AFOS support.

In addition, we met with the major contractors who have supported NWS in developing AFOS, to obtain information on studies prepared to justify AFOS and to gain a better understanding of how the system performs and is planned to perform. We also interviewed key personnel and reviewed pertinent documents at all major NWS headquarters support offices. The Director of NWS and the Director of our Community and Economic Development Division corresponded during the final phase of our review. This exchange addressed our concern that management and technical deficiencies were impediments to implementing AFOS. The Director of NWS stated that improvements recently made support NWS' position that AFOS is working satisfactorily and that it should be implemented. After providing NWS with a copy of our draft report for official review and comment, we continued to perform onsite audit work. This additional work, performed in response to a request contained in a report of the House Committee on Appropriations, 1/ consisted of observing NWS' August-September 1981 validation test of AFOS at

---

1/House Appropriations Committee Report 97-180, July 16, 1981, p. 14.

selected sites in the western and central regions. We also reviewed the preliminary results of the validation test and discussed our observations with the Director of NWS, the AFOS project manager, and other key officials. We met with officials of the National Oceanic and Atmospheric Administration and the Department of Commerce and obtained information on their involvement in approving AFOS and concerns over the project's development.

## CHAPTER 2

## STATUS AND COST OF AFOS

NWS began planning for the AFOS system in the 1960's and began developing it in 1974. AFOS was to be fully operational by August 1979 at a cost of $77.6 million. However, the project has been delayed by severe technical problems with hardware, software, and telecommunications. In addition, for various reasons AFOS will not realize expected cost savings. AFOS development costs have been understated because NWS did not use standard accounting procedures and controls. By our best estimate, as of September 30, 1980, NWS had spent $100 million on the project, and the earliest that AFOS could be fully operational is 1984.

Even if AFOS were fully implemented by 1984, the system planned to be made operational is not the AFOS originally designed but a system with limited capability. NWS indicates that it plans to design and develop a new system that will meet original requirements. This system is estimated to be completed in 1989 at a cost of $125 to $150 million. If, as planned, NWS uses AFOS on an interim basis until the new system is completed in 1989, AFOS could cost an additional $144 million.

### CURRENT STATUS OF AFOS

AFOS has been phased into actual field operations over the past several months and is now being used as a primary tool by forecasters in the preparation and delivery of weather services in selected field offices. Currently, the sites using AFOS are located in two of the four contiguous NWS regions--western and central. By the end of fiscal year 1982, NWS anticipates full implementation of AFOS at all planned sites in all four contiguous regions. NWS plans to continue using the current communications system operated by FAA through the end of fiscal year 1984.

All AFOS hardware, software, and telecommunications are installed with all four regional loops being driven by the System Monitoring and Coordination Center. Based on the validation/demonstration test that was conducted in August-September 1981, NWS believes that the performance of AFOS will continue to improve as field personnel gain experience and system deficiencies are corrected.

Despite these improvements, AFOS still has problems with software, hardware, and telecommunications that prevent it from performing as originally planned and that make future development and enhancement difficult. In early 1981 NWS conducted an operational test to assess these problems. Following this test the

Director of NWS stated in a memorandum 1/ that solutions to problems affecting future development and enhancements of the system, such as integrating radar and satellite data, were not possible without a major redevelopment effort, including replacing the software, hardware, and telecommunications systems. The Director further stated that the addition of any further capabilities needed to support current operations is not possible, and in fact some capabilities already in AFOS would have to be removed in order to stabilize it. For example, some of the disaster protection and system recovery features have been removed.

Other problems were disclosed in the memorandum that will prevent the system from operating reliably. Examples of these include fault isolation and identification, the ability to monitor the status of the network, recovery from degraded modes of operation, message composition, and the ability to send messages through the NOAA Weather Wire. The effect of these problems is a reduction in the quality of service NWS can provide, greater risk of field offices not being operational, and an increase in AFOS operating costs. AFOS development continues in an effort to correct these and other deficiencies.

In August and September 1981, NWS conducted a second major operational test on the basis of which NWS was to decide whether to continue developing AFOS or abandon it. The criteria against which AFOS was judged in this test were limited. (See ch. 7 for further discussion of test criteria.)

Regardless of the final results of the operational test, still being assessed at this date, NWS plans to develop a new system that should overcome the deficiencies of AFOS and meet future needs. Although planning for this system has just begun, the Director of NWS estimates that it could be operational by 1989 and that its costs of $125 to $150 million would be comparable to a completed AFOS system.

## ACCOUNTING PROCEDURES

Some costs that should have been attributed to the AFOS program have not been included in NWS' AFOS cost figures. We examined NWS' AFOS cost data and determined that AFOS program costs have been underreported by about $18 million. Further, costs have not been classified or presented to management in a meaningful and useful format. These shortcomings occurred because NWS did not use project cost accounting techniques that require detailed cost identification data and did not establish reporting or control mechanisms. Although we informed NWS of these deficiencies, it still has not established a good accounting system

---

1/National Weather Service Director's memorandum to NWS regional and office directors regarding "AFOS National Implementation Decision," March 19, 1981.

for AFOS. Moreover, future AFOS development costs will continue to be understated.

Two primary documents cover accounting procedures required for major systems. These are Office of Management and Budget (OMB) Circular A-109, "Major System Acquisitions," and Federal Government Accounting Pamphlet Number 4, "Guidelines for Accounting for Automatic Data Processing Costs." Both documents point out the necessity to identify significant elements of costs directly related to acquiring systems so that informed management decisions may be made at each phase in the entire life cycle of a system. These decisions include the most economical time to replace a system and alternatives in acquiring new systems. In summary, these documents state that accumulating the purchase cost of the system's components is only one step in determining the system's total cost. An agency must further determine the costs of all resources, including personnel involved in developing, procuring, installing, and testing the system, including the system's software. A system must also be assigned its share of the rent or lease expense of buildings, utilities, and management overhead. Additionally, training costs are an integral part of a system's development expense.

Life-cycle costing as required by OMB Circular A-109 requires an agency to accumulate all direct, indirect, and recurring costs of a system for each phase of its life span. Under this practice a system remains in its development phase until it can perform the function for which it is intended.

The cost of personnel is the primary area in which AFOS development costs were not collected. For example, training costs included only the cost of providing the training, and not the higher salaries and travel costs of personnel receiving the training. Also, personnel costs for development, testing, and management have not been reported. Because NWS' development approach to AFOS included many people actively involved with the AFOS project, the magnitude of this personnel cost problem is significant. For example, the western region reported that in one 5-month period, over 3,500 hours had been devoted to AFOS that were not charged to the AFOS project.

Overhead is another area in which costs were not applied to AFOS. A proportionate share of an agency's management and administrative expense should be applied to a project's costs in addition to overhead expenses such as utilities and rent. These are significant expenses for a comprehensive ADP system such as AFOS.

NWS has not accounted for other AFOS development expenses by transferring to operational accounts all maintenance and parts expense for the AFOS hardware. During installation and testing these expenses have been considerable. Further, because AFOS is not an operational system, these expenses should be considered developmental.

NWS accounting procedures did not accurately allocate or record expenditures in the following cost categories:

--Increased utilities (primarily electricity) and space required to support AFOS.

--Additional air conditioning installed at field sites to meet regional AFOS environmental conditions.

--New facilities required for NWS field offices, in part due to AFOS, and modifications to facilities required to support AFOS hardware.

--Management overhead at the field and headquarters level which was not applied to AFOS development costs. For example, the salary of the AFOS project manager was not charged to AFOS over the last 7 years of development.

NWS has not corrected accounting deficiencies

In November 1980 we informed the Director of NWS of the deficiencies in project accounting. However, NWS still does not include overhead and staff costs in computing future AFOS operating and development costs. For this reason operating costs are understated by approximately $2.1 million annually. As a result, AFOS operating costs from fiscal years 1981 through 1989 will be about $18.9 million higher than reported by NWS.

Essentially, NWS regards personnel costs as a fixed expense, even though Government policy regards them as a variable expense. The cost of AFOS personnel to NWS is lost to other projects to which their time could have been devoted. The Director of NWS indicated that it was unnecessary to charge these costs to AFOS because NWS would incur them with or without AFOS. Federal accounting regulations, however, require that personnel costs be assigned to the project.

AFOS DEVELOPMENT COSTS TO DATE

A partial accounting of AFOS development costs was available in the NWS accounting system, and NWS at our request provided a list of estimated unaccounted costs in identified areas. These figures place AFOS development costs through fiscal year 1980 at about $100 million. According to NWS, it received $77.6 million in congressional appropriations specifically for AFOS; $5.9 million in additional NWS resources acknowledged by NWS; and $18 million, primarily for personnel, that has not been recorded by the NWS accounting system. The misallocation of these expenses to other NWS programs occurred primarily because NWS has not exercised management controls over AFOS development and costs.

Our concern is the absence of cost information for NWS and the Congress to use in managing the project as the funds are

budgeted and expended. If NWS is to have needed information for managing the program in the future, complete AFOS cost collection procedures are required. This is particularly relevant in light of the additional $144 million NWS plans to spend on AFOS and a potential $125 to $150 million it plans to spend on developing a new system. We identified expenditures of about $18 million that were unaccounted for in the areas of overhead, training, and some personnel costs.

GAO Estimates of AFOS Costs
for Fiscal Years 1974-80 (note a)

| | |
|---|---|
| Hardware | $ 64,038,250 |
| Software | 12,744,150 |
| Training | 1,525,900 |
| Communications | 871,900 |
| Uncollected costs (primarily personnel) | 18,000,000 |
| Expenditures, fiscal 1974 and fiscal 1975 (note b) | 2,980,000 |
| Total | $100,160,200 |

a/These figures are rough approximations.

b/The AFOS project did not appear as a budget item until fiscal year 1976 and costs were not separated before that time.

Current NWS accounting procedures do not provide management with information and assurance that funds are spent effectively. Further, no system exists to compare allocated funds with actual expenditures. Once AFOS funds are allocated, actual expenditures are not tracked. Moreover, existing accounting procedures do not provide for establishing accounts for capital equipment costs. Software costs are not separated from other costs, and hardware costs include only procurement and not installation or testing.

## AFOS COST SAVINGS WILL NOT BE REALIZED

AFOS was originally planned and presented as a system that would, among other objectives, pay for itself through increased efficiencies. These savings were to result from eliminated or avoided positions, removal of the current communications system, and greater employee productivity. The savings have been delayed and the efficiencies, in our opinion, will not occur. Further, AFOS will not pay for itself through savings but will require at least $15 million annually for operating costs as opposed to about $4 million needed annually to operate the current communications system.

NWS estimates that AFOS' annual operational costs will be $13 million and that $2.6 million in savings can be achieved by removing part of the current system. We determined that the NWS estimate does not include $2 million in annual overhead cost, bringing our estimate of AFOS' operational costs to $15 million annually. We also believe NWS cannot remove the current communications system and will not achieve the $2.6 million in annual savings it has estimated for this change.

The current system which AFOS is to replace is operated primarily by FAA; NWS pays only for direct support expenditures and the equipment it connects into the system. As NWS implements AFOS, it must not only support a vastly more complex system at the field level but must also assume the cost of system development, management, and maintenance--functions currently provided at no cost by FAA.

Over a 7-year development period the AFOS system has changed in many ways. Changes in basic operating requirements for the system have been caused by operational and design considerations. The current communications system AFOS was to replace in 1979 will now remain in operation as a backup through at least 1984. NWS staffing levels have also changed, and many positions that AFOS was to eliminate have already been removed by budget cuts. NWS now recognizes that AFOS will not produce cost savings equivalent to or exceeding its development and annual operating costs. At the same time, the AFOS system as currently designed will provide new services and greater capabilities than the existing system. However, NWS has yet to perform a full cost-benefit analysis to compare the capabilities and benefits of AFOS, as it is designed today, against the total costs of continuing to rely on the current communications system without AFOS.

## POTENTIAL COSTS TO COMPLETE AFOS

NWS plans to develop a new system to meet future needs and overcome the deficiencies of AFOS. NWS intends to operate AFOS, despite its deficiencies, while the new system is being developed. The future cost of the AFOS system shown below is based on data provided by NWS.

Future Cost of AFOS
Fiscal Years 1982-89

| | (000,000 omitted) |
|---|---|
| Operate present FAA communications system (note a) | $ 6 |
| Complete AFOS and operate through 1989 | 138 |
| Develop new system | 125 |
| Total | $269 |

a/NWS plans to remove the current communications system in 1984.

## CONCLUSIONS

AFOS will not generate the cost savings originally envisioned but will incur $15 million in additional annual operating expenses. The AFOS project is 5 years behind schedule; has cost $100 million, $22 million over budget; and has fewer capabilities than its original design. Yet AFOS still falls short of meeting needed requirements. Therefore, NWS needs a new system that can perform many of the functions for which AFOS was originally designed.

NWS' current communications system is scheduled to remain in place to back up AFOS until at least 1984.

NWS did not follow established Government regulations and guidance in accounting for AFOS costs. As a result, NWS does not take into account the true cost of AFOS development. Further, by not following these regulations, NWS is understating future operating costs by $2 million annually.

## RECOMMENDATIONS

We recommend that the Secretary of Commerce direct NWS to

--account for all AFOS costs, including the full personnel costs attributable to developing and using AFOS, and

--follow accounting regulations prescribed in OMB Circular A-109 in accounting for system development costs, including life-cycle costs.

## AGENCY COMMENTS AND OUR EVALUATION

NWS disagreed with our conclusions that the AFOS project is 5 years behind schedule and that its development stage will be completed when NWS has fully implemented AFOS and removed the current telecommunications system run by FAA. NWS has estimated that this process will be completed in 1984, 5 years after its original estimate of 1979. NWS' position is that AFOS' development will be complete when all scheduled offices are using AFOS, which it expects to occur in 1982.

AFOS will be fully operational, in our view, only when the current system is removed in 1984 and all stations are using AFOS. In its internal plans developed before responding to our report, NWS considered removal of the current system as the end of the development phase, just as we do. Furthermore, in the private sector and in Government, the time of removal of previous systems is an accepted management practice for indicating the end of a development phase. By this measure, AFOS is 5 years behind schedule.

NWS stated that we had overstated AFOS development costs by at least $11 million. NWS attributed this amount to (1) a

conceptual difference in applying overhead and (2) differences in applying costs for personnel involved in routine support functions. NWS further maintained that planned AFOS spending has been based all along on using personnel funds in conjunction with other reprogramed development funds.

NWS maintains that its application of overhead is consistent with the NOAA financial system, which GAO approved. It is our contention that NWS did not use the GAO-approved accounting system and its method of applying overhead for the AFOS project. There is no evidence showing that the correct overhead was applied to the future AFOS program cost estimates. Also, the NWS resource management staff confirmed that overhead was not applied to AFOS costs.

A point of difference between NWS and us is the assignment of costs for all AFOS developmental staff. NWS attributes many of these personnel costs to "routine cross utilization of support." The magnitude of NWS' "cross utilization" is large, amounting to tens of thousands of hours. Further, the work performed by these personnel was the direct development, maintenance, and testing of the AFOS system. It should therefore be charged to the project. Further, in the 1976 Program Development Plan, NWS specified the resource requirements for AFOS and did not include the use of existing funding or reprogramed funds. In its response NWS stated that it intends to begin charging appropriate direct labor costs to the AFOS program, including the project manager's salary.

NWS stated that it is not necessary, as we recommend, that it follow accounting procedures prescribed in OMB Circular A-109. It stated that the Department of Commerce did not implement A-109 until 1978 and that "at that point the acquisition of the AFOS system was so nearly complete that it was not considered to be applicable." While it is true that the AFOS hardware was purchased by 1978, approximately $60 million has been spent since then on continuing development efforts.

OMB Circular A-109 covers costs beyond the purchase of components. Its approach is based on the principle that an accurate picture of system acquisition costs can be gained only by viewing a system's entire life-cycle costs. Life-cycle costs would therefore include testing, operating, and supporting the AFOS system. The requirements of A-109 should have been followed.

NWS also stated that the recommendation to follow OMB A-109 is unnecessary because "NWS will, as it has in the past, comply with Department of Commerce's accounting system." We believe our recommendation is still valid. As we note in the report, NWS' application of overhead and personnel costs to AFOS has not been in accordance with the Department's or NWS' own procedures. Further, as NWS noted in its response, it has been required by

the Department of Commerce to use OMB A-109 since 1978. This requirement is still not being met.

NWS also objected to our estimate that developing a new system would cost $125 to $150 million. We based our estimate on AFOS development costs which, when completed, will reach $150 million or more. This is the only historical basis for an estimate. With the effects of inflation on personnel costs for software development (the major costs of an ADP system), it is very unlikely that a new system would cost less than $125 to $150 million. Our estimate is also consistent with an NWS' estimate on March 19, 1981, of the approximate cost of a new system.

Although additional funds may be required to maintain the current communications system, continuing to operate AFOS would be considerably more expensive. This is especially true in view of NWS' March 1981 technical assessment which states that between $12 and $15 million will be required to upgrade AFOS to a minimum level of acceptability. This does not include any spending to resolve basic AFOS design deficiencies and constraints.

NWS stated that we did not offset the benefits of AFOS against the cost savings from not operating the system. During our review of AFOS we made clear our view that NWS should prepare a cost-benefit analysis of AFOS. Yet, NWS stated that this was unnecessary and that it had no plans to conduct such an analysis. Without the needed benefit and cost information, neither NWS nor any other reviewing organization, including NOAA, cognizant congressional committees, or our staff, can offset benefits against costs. However, we did find that the cost savings that NWS originally identified as AFOS benefits will not be realized.

NWS stated that the cost to operate and maintain AFOS is close to the original projections made in 1976. Since we did not review this aspect, we have no basis to accept or reject NWS' statement. Given the lack of cost data available from the NWS accounting system, we did not attempt to determine the cost to maintain and operate the system. Our review focused on the costs to develop AFOS. We have made use of NWS figures for operations and maintenance, making clear that they were provided by NWS. The only adjustment we have made was to allocate overhead to the NWS figures as required by NOAA and NWS accounting procedures.

NWS stated that it disagreed with our position that over $100 million scheduled to be spent in small pieces over 8 years could be accumulated for the procurement of a new system. We do not assume or state that this is the case. A new system development project should be separately approved and funded by the Congress and not internally reprogramed from operations and maintenance funds.

Our continuing concern is that NWS has not adequately determined the most cost-effective course of action. Further, NWS has not adequately demonstrated that splintering its scarce personnel resources across three separate projects--maintaining and developing AFOS, maintaining the current system, and developing a new system--is cost effective and feasible.

NWS' comments are summarized in appendix I and presented in their entirety in appendix II.

## CHAPTER 3

## THE MANAGEMENT OF AFOS HAS BEEN INEFFECTIVE

A direct cause of many AFOS technical and operational problems described in this report has been the absence of a coherent approach to managing this large and complex effort. Most of the delays and increased costs associated with the AFOS project have occurred because NWS did not (1) establish clear responsibility for AFOS in a single, full-time manager, (2) use standard approaches to managing complex ADP projects, and (3) recognize the need to seek additional outside assistance in developing AFOS. NWS needs to address these management deficiencies regardless of the ADP system it develops and installs.

### BETTER PROJECT MANAGEMENT IS NEEDED

For over 12 years we have reported on the problems associated with developing software application systems in the Federal Government. About $300 million in waste was identified in these development efforts. We reported that this waste of money and effort could have been mitigated through adherence to generally accepted management principles such as the following:

--Developing comprehensive project plans that address all aspects of the system and tie in with other agency software plans.

--Assigning project managers as the central point of authority for major software development efforts.

--Preparing realistic cost estimates and economic analyses.

--Establishing effective procedures to compare a system's progress with the approved cost, schedule, and performance estimates.

The AFOS project has not adhered to these principles. NWS made plans, but they were not often implemented or followed. In developing AFOS, NWS did not develop comprehensive plans addressing all aspects of the system and its effect on other NWS systems and projects. Also, NWS did not establish an effective project management office or use economic analysis as an effective tool for managing and controlling AFOS development.

AFOS has been directed and developed by staff members who are involved only part time and have not been relieved of their normal responsibilities. These part-time staff members are required to balance their primary duties against responsibilities for AFOS. Acquiring the knowledge needed to develop a system as complex as AFOS, and then carrying out its development, demands a greater time commitment than AFOS staff members are able to provide under present circumstances. This problem has resulted in a

lack of accountability, unclear lines of authority, and a staff that has at times worked at cross-purposes.

Major AFOS decisions are left to the Director of NWS or his deputy, but these officials are occupied by wide-ranging responsibilities and cannot be expected to manage the project on a day-to-day basis. The result is that AFOS' problems have not been addressed in a timely or effective manner.

NWS is aware of these problems. In a March 19, 1981, memorandum, the AFOS project manager stated:

> "Many of our problems can be traced to failures of management and systems discipline. These have led to unrealistic plans, schedules and expectations. Priorities in allocation of staff and resources have been obscure, confusing and inconsistent throughout the organization. The flow of up-to-date, authoritative, honest information has been spotty and slow, and the exercise of management direction often has been weak and fuzzy. Collegial decision-making has promoted participation at the expense of focus, clarity and decisiveness."

## NWS has used a decentralized approach to develop AFOS

NWS normally operates under a decentralized management structure. It allows its field offices independence in carrying out their responsibilities, and no NWS' major headquarters or field office has authority over any of the others. The Office of the Deputy Director of NWS is the lowest level at which disputes can be mediated and NWS-wide policies established or enforced.

AFOS was expected to produce substantial changes in NWS' day-to-day operations. For this reason, a well-intentioned but ill-advised attempt was made to share responsibility for AFOS development among as many people as possible. Thirteen major NWS offices were assigned various responsibilities for developing AFOS. These responsibilities were in turn often shared with several other offices. For example, 4 offices were responsible for system development and experimentation, 5 offices were responsible for coordinating AFOS with external systems, and 12 offices were responsible for training. In addition, several committees were established at NWS headquarters for program coordination and problem solving.

The Deputy Director of NWS was initially responsible for directing the activities of all people and offices involved with AFOS. However, high turnover in this position led NWS to assign the responsibility to others during the course of the project. Currently, project management is assigned to the director of an NWS headquarters office, but this individual is

not sufficiently high up in the organization to enforce policies agencywide, and most of the staff members responsible for development do not report directly to him.

AFOS decentralization has created development problems

Because of NWS' decentralized management approach to AFOS, key managers frequently lack the authority to carry out their responsibilities or enforce their development decisions. An example of unclear lines of authority is NWS' handling of the AFOS air conditioning. Field sites experienced systems failures which they attributed to heat problems. When NWS engineers investigated the problem, they determined that field sites did not require special air conditioning, because defective internal fans were causing the problem, and directed that air conditioning not be purchased. In spite of this decision, NWS regional managers proceeded to install air conditioning because they believed it was necessary. In short, a directive issued by the office having responsibility for engineering decisions had no effect on the regions' purchasing decisions. In addition, no NWS official short of the Director has sufficient authority to enforce AFOS development directives.

Our primary concern is that offices with responsibility for AFOS decisions have no authority to enforce their policies. This lack of coordination has also prevented NWS from achieving potential savings through a consolidated single-purchase contract. For example, management had no assurance that offices purchased sufficient and appropriate air conditioning to meet their needs.

Without a strong central management office with sufficient authority, the NWS project structure precluded effective coordination and accountability in systems development. Because of these problems:

--Top management received inadequate and misleading information on the time and resources required to complete development and on the quality of the system.

--Development priorities were not clearly established and top priority work was ignored in favor of lower priority work. For example, monitoring software provides necessary controls over the status of all field office systems on each regional loop at all times. This information is critical to taking corrective action when a field office system malfunctions. Nevertheless, NWS programers were removed from developing the SMCC's monitoring software, a critical AFOS requirement, and assigned to the development of enhancements which are valuable but not critical to the system's operation.

--Programers acted independently of the system managers and developed software not approved for the system. For example, numerous enhancements requested by field

personnel were developed and incorporated into the system without being reviewed or approved by project management.

--Resources were frequently wasted because decisions were based on unrealistic completion dates. For example, the director of the western region informed the Director of NWS in September 1980 that the western region had expended substantial resources preparing for a precommissioning test based on assurances that the development staff at headquarters could meet promised completion dates. The test slipped because the headquarters staff missed its completion dates and failed to provide the promised support.

AFOS development personnel work at cross-purposes

AFOS development personnel assigned to headquarters and field offices report to the heads of their respective offices rather than to a central AFOS project manager. This reporting structure has resulted in work that was done at cross-purposes. For example, the two regions most actively involved in developing AFOS assigned a top priority to making it operational. Yet, during the past 3 years headquarters has stressed the importance of testing and validating the AFOS system prior to going operational. The two approaches are contradictory: one attempts to determine status and problems; the other attempts to go operational as quickly as possible and analyze the system later.

This situation placed a significant burden on headquarters development staff, who had planned to test and document AFOS before developing it any further. These individuals were pressured by field personnel to develop new software and procedures required for operations.

Another example of poor coordination occurred in developing key software. The western region believed a key cause of AFOS' problems was the inability of the System Monitoring and Coordination Center to monitor the status of the telecommunications network--that is, to know which field offices are operational and which have failed and been cut out of the network. Headquarters development staff assigned this function a lower priority. As a result, the western region expended considerable resources developing software designed to accomplish this task and intended for use at the SMCC. When the SMCC attempted to use the software, it did not work. The software will require a complete redevelopment to make it operational.

The lack of success with this specialized software is not surprising. The programer developing it in the western region did not have access to SMCC personnel who were familiar with the equipment on which the software would operate. The programer lacked the required knowledge and experience of the SMCC's unique

monitoring and control operation and did not have the proper test-bed for developing the software. The same resources expended by a programer working at the SMCC rather than in a field office, and furnished with the required information and test facilities, would probably have produced a more useful product.

## NWS DID NOT APPLY ACCEPTED APPROACHES TO MANAGING LARGE PROJECTS

The National Bureau of Standards has developed and issued guidance for Federal agencies in developing ADP systems. These standards are similar to those used by the private sector in systems development. They are widely accepted.

Although NWS recognized the need to use standard project development techniques, it did not properly utilize these techniques in developing AFOS. For example, management was not provided with timely and useful project status reports and adequate cost information to aid in decisionmaking, and most of the cost information available was in error.

Similarly, the use of management reviews was of limited value because insufficient information was available to the project manager and the Director of NWS. For example, headquarters management recently reviewed the need to dedicate one person at each field office to work full time on AFOS maintenance and operation. However, the regions had already assigned a full-time staff member at each field office, in some cases as early as 2 years before the headquarters evaluation. We believe this information on staff assignments should have been available to headquarters management since the action of regional management, in effect, dedicated over 100 staff members to the project. Headquarters was aware of the heavy commitment of field resources but not the extent of that commitment. The absence of accurate information on actual conditions severely reduces the value of central planning and management, the quality of the decisions made, and management efficiency in allocating resources.

AFOS is among the largest nonmilitary distributed computer systems ever designed. Developing such a system requires a highly trained and experienced staff of managers, designers, and programers. In addition, developers should have the necessary hardware facilities to test the system. However, due to inexperience, NWS did not increase its staffing to accommodate the project. Many of the NWS headquarters and field people working on AFOS have other duties and are providing AFOS support only on a part-time basis. Further, NWS has shifted staff members from one ongoing task to another, thereby reducing the quality of their work and introducing confusion over responsibility and accountability.

NWS had not previously undertaken any ADP development projects of the size and scope of AFOS. Further, the individuals who have served as project manager and in other key management positions have had little or no experience in managing the development of large ADP systems.

The lack of experience with large ADP projects was a significant cause of NWS' project management problems. NWS believed the key difficulty in developing AFOS was the system's hardware. In fact, with most systems the crucial difficulty is software development, and AFOS is no exception. Because NWS had experience with projects like radar, it concentrated on developing hardware rather than software. Further, NWS' belief that the major AFOS development effort would be hardware contributed to its decision to manage and develop the system in-house. As a result, AFOS has been managed and developed by people who are not sufficiently experienced in ADP software development.

NWS seriously underestimated the size of the AFOS development effort and as a result allocated inadequate resources to the project. Underestimating time and resources resulted in the following problems:

--NWS installed some telecommunications lines earlier than needed. These lines had to be removed very shortly after installation to reduce costs. They were reinstalled later.

--The AFOS managers made several decisions based on arbitrary deadlines, not needs. One of these decisions, not designing and developing the SMCC subsystem to meet its specialized monitoring and control needs, continues to prevent successful software development today.

--NWS provided unrealistic completion estimates to the field resulting in increased costs, morale problems, and a loss of credibility. For example, NWS' plans allocated insufficient time for developing, testing, and installating the software and imposed unrealistic deadlines. Actual development time was about 4 years. Because of these unrealistic deadlines, developers disregarded testing, documenting, and other development procedures in an effort to meet deadlines.

--NWS assigned responsibilities to developers who lacked the training and experience to carry them out. For example, the programers who modified the hardware operating system, probably one of the most complex of software efforts, had limited experience with writing operating systems.

## INEFFECTIVE USE OF CONTRACTORS

NWS has not made effective use of consultants and associated studies that it commissioned in developing AFOS and has not made appropriate changes in its management structure when consultants advised it to do so. Had certain consultant recommendations been adopted, AFOS' problems could have been mitigated. For example, in 1979 NWS engaged one contractor to assess the AFOS software design and another to review the remainder of the AFOS program in greater depth. Its recommendations included:

--Stopping the entire AFOS development and establishing a formal management structure before proceeding.

--Developing only a limited test network and, in parallel, redoing the AFOS system from the top down before going operational.

--Reordering the priority of system development activities.

In our opinion, it is difficult for managers and staff who are primarily trained in meteorology to develop a complex, state-of-the-art, distributed minicomputer system. We have discussed these concerns with the Director of NWS and other agency officials. It is our position that contractors experienced in developing major ADP systems should be engaged for the new development effort, and NWS should contract out development work beyond its internal capabilities and concentrate NWS resources on requirements analyses, system definitions, and managing the contractor's performance.

We believe that greater reliance on outside contractors could substantially improve NWS' success in developing a new system. This should also relieve the staffing problem because fewer NWS people would be involved as the contractor performs most of the time-consuming technical work. Further, contracting should improve the quality of the system because the actual developers will be personnel trained and experienced in ADP.

The main thrust of recommendations from several studies was that NWS should establish a strong project management office, increase systems discipline, use standard project and software development procedures, and completely redevelop large portions of AFOS. The agency, however, finds it unacceptable to impose a strong project management office on NWS' decentralized management structure and has not adopted the consultants' recommendations on the need for an improved structure.

## CONCLUSIONS

NWS did not establish an effective project management office with a full-time project manager having complete authority for development. Project personnel were assigned part time and sometimes worked at cross-purposes. NWS did not adequately assess the magnitude and complexity of the AFOS project and therefore did not assign a full-time manager with authority equal to the responsibilities of the assignment.

The result of this lack of clearly defined responsibility for AFOS has been NWS' inability to effectively manage the project. NWS is a highly decentralized organization which permits wide latitude to headquarters and field staffs. Although this organizational arrangement may be acceptable for other NWS activities, it is incompatible with developing ADP systems such as AFOS. In developing a new system, NWS needs to address this problem if the development is to be successful.

NWS neglected to apply basic systems management principles to AFOS. NWS' use of project management techniques was ineffective because managers lacked experience, adequate enforcement, and feedback systems.

## RECOMMENDATIONS

We recommend that the Secretary of Commerce direct NWS to

--establish a project management office and assign all development personnel to that office on a full-time basis in completing AFOS development and in developing a new system;

--appoint a project manager with clear authority for AFOS and for the planned new system;

--select and enforce standard software development procedures, including documentation and testing for the new system; and

--contract out system development activities which exceed in-house development capabilities.

## AGENCY COMMENTS AND OUR EVALUATION

NWS stated that it has already implemented the recommendations in this chapter that apply to the current AFOS project and that its future plans related to managing the development of a replacement for AFOS reflect our recommendations.

NWS stated that it has established a project management office for AFOS and that it has assigned all development personnel to that office on a full-time basis. Further, it stated that it has appointed a project manager with clear authority for the AFOS project. In developing the new system, NWS plans to adopt and enforce standard software development procedures. These procedures would include documentation and testing of the new system. For the new system development project, NWS agreed it should engage a contractor with experience in complex and comprehensive computer/telecommunications systems development projects.

In our view, the scope and magnitude of NWS' effort to automate requires even greater emphasis on strong centralized management than shown by NWS to date. Specifically, the management of a project like AFOS should include individuals with experience in managing large and complex ADP telecommunications projects. Having the project manager report to the Director of NWS does not in itself adequately address the problem of managing and controlling a complex and comprehensive project like AFOS. Our review disclosed that the AFOS project manager had only limited control over the resources critical to project development. Specifically, personnel reported to their normal

offices; were evaluated by managers other than the AFOS project manager; and, to a large extent, were assigned to AFOS on a part-time basis.

NWS also stated that AFOS project personnel continue to report to and be rated by their normal supervisors and not the AFOS project manager. This is a primary problem in NWS' management of AFOS. If these personnel are in fact assigned to AFOS development on a full-time basis, they should report to the AFOS project manager and not to their normal supervisors.

We agree with NWS' statement that management deficiencies are not valid reasons for not using a system after technical problems have been resolved. Our report concludes that NWS should defer implementing AFOS on the basis of technical deficiencies and not because of management problems. However, our report also points out the extent to which management deficiencies contributed to the technical deficiencies.

NWS' statements regarding its reorganization of the AFOS management structure do not adequately address our concern for lack of centralized control over AFOS development. The reorganization of AFOS management continues NWS' policy of the project manager functioning as a coordinator of work performed in a number of different offices. It still does not provide a single source for decisionmaking on AFOS and it does not assign full-time development staff to a project manager who can directly manage their activities. Therefore, the need for a strong project management office with complete authority to make key decisions remains unfulfilled.

The extent and effect of AFOS management deficiencies has been assessed several times during the life of the project. In 1979 NWS contracted with two ADP consulting firms for comprehensive reviews of AFOS. Both reviews were completed in late 1979. The first report's assessment of NWS management and its structure was as follows.

> "The AFOS program is of sufficient magnitude to warrant a distinct project management office with sufficient authority to obtain binding commitments from support organizations within the NWS structure. Because of these organizational deficiencies, the day-to-day business of AFOS program management became diffused throughout the NWS, and program commitments became entangled with other NWS day-to-day business. There was no driving force--a project management office--to maintain program momentum, to provide authoritative leadership, and to be accountable for the job."

The second review by a contracting firm summarized its concerns with AFOS management as follows.

"The most critical need is the establishment of a strong and permanent management structure for AFOS."

Our review, initiated about 1 year after these reports, identified similar management and organizational deficiencies. In short, the AFOS project management structure provides little overall control and guidance to the system development activities. These conditions continue to exist, and their effect hampers progress toward developing a new system to meet agency needs.

In this report we state the need for a contractor's expertise to develop complex technical systems such as AFOS. We still contend that the technical work of developing major ADP projects should be accomplished with personnel who have ADP/telecommunications training and experience in developing complex systems, as opposed to using meteorologists who lack this experience.

NWS noted in its response that it did use contractors for AFOS development. NWS did hire a number of contract programers who were used in AFOS development under the direction of NWS managers. They were of considerable assistance to NWS. However, given the size of AFOS and the limited amount of outside assistance used, it did not adequately address NWS' staffing problems. Major ADP development projects simply require too much staff time to be developed without extensive contractor assistance or hiring of full-time ADP development personnel.

NWS also said that management must retain the responsibility of NWS. We completely agree. However, using contractor personnel to perform technical tasks does not diminish NWS' management authority.

We note that NWS has taken steps to implement two of the recommendations in this chapter and plans to implement the remaining two when it develops a new system. We continue, however, to have reservations about the adequacy of NWS' changes to its management structure. There remains a crucial need, still not recognized by NWS, to develop a stronger central AFOS project management structure.

NWS stated that different personnel are involved in developing a new system and in operating AFOS. As a result, NWS believes it can concurrently develop a new system, operate AFOS, and maintain the current system. NWS has not fully acknowledged that during AFOS' very lengthy and costly development phase, field operating personnel invested vast amounts of time in developing, testing, and operating the system. This time expenditure is likely to be repeated when NWS is again involved in a new system development effort. Managing and developing AFOS has already strained NWS field and headquarters personnel. Developing a new system, in addition to supporting AFOS and maintaining the current system, will place an unrealistic burden on both management and technical personnel. Further, by not adequately

assessing the total personnel needs based on a system to properly account for personnel costs, NWS will continue to ignore the very real and heavy investment of its personnel in AFOS development.

As we stated in chapter 2, NWS should follow the management and cost accounting procedures outlined in OMB Circular A-109. This minor change in itself would help management recognize the total cost of development and provide a sounder basis to determine personnel costs for all development and operating activities. Over the next several years, significantly more staff resources will be required to operate and maintain AFOS than those needed to operate the current communications system.

NWS' comments are summarized in appendix I and presented in their entirety in appendix II.

## CHAPTER 4

## THE AFOS SOFTWARE PROBLEMS PERSIST

NWS' problems with the AFOS software have been a major cause of delays. The software to which NWS is committed has not met all the requirements initially established for AFOS. NWS' current and final attempt to remedy some of the software deficiencies cannot overcome its fundamental defects. NWS did not take advantage of generally accepted software development procedures, including documentation and basic testing, to validate the system's design and performance.

### AFOS SOFTWARE CANNOT MEET NWS' NEEDS

Software is defined as a detailed set of instructions which controls hardware and enables the computer system to manipulate information and carry out user tasks. As hardware costs continue to decrease, software has become the most costly item in ADP systems. The AFOS software will require continual maintenance and modification to meet changing user needs and new requirements.

In the AFOS system, software is divided into three categories--applications, operating system, and telecommunications. The application software includes a set of instructions that produces products or outputs for end users. The AFOS operating system software is housed in the minicomputers to control and direct the computer to carry out various functions. The third type of AFOS software controls and directs the functions of the telecommunications system to transmit data over the telephone lines to and from a weather station.

According to the AFOS functional specifications, the software was to meet three major requirements: (1) take information from the telecommunications system and store it for developing forecasts, (2) retrieve data stored in the system so that forecasters can analyze it, and (3) minimize the work involved in composing and sending weather information to users. In addition to meeting these broad requirements, AFOS was planned to include other characteristics. The system was to

--be highly reliable (NWS initially specified that the software should not malfunction more than once a year (see footnote on p. 39)),

--be flexible enough to accommodate future system enhancements,

--be able to provide backup capability in the event of a malfunction,

--support multiple users of the system at each site on a concurrent basis,

--provide quick response time to users, and

--be simple enough in operation that it could be maintained by forecasters with minimal ADP experience and training.

The software developed for AFOS does not meet these characteristics initially specified by NWS. Further, the software lacks the capabilities to meet minimal system requirements, frequently fails, requires extensive staff time to support, and requires a trained computer specialist onsite to maintain operations at an acceptable level.

We believe a primary cause of NWS' software problems is its inexperience with large software development projects. In part, this problem is also caused by the changes occurring in ADP technology. In the early days of computers, the price of the equipment (hardware) was the major ADP cost. Also, the computer programs (software), which make the equipment operate, were relatively inexpensive. However, software now costs considerably more than hardware, which has steadily declined in price because of technological advances. We noted in our recent report, "Wider Use of Better Computer Software Technology Can Improve Management and Reduce Costs" (FGMSD-80-38, Apr. 29, 1980), that recent studies predict that by 1985, over 90 percent of the cost of ADP will be attributable to software. Our discussions with NWS managers and developers made clear that NWS believed the higher priority task in developing AFOS was the design and procurement of its hardware. As a result, procedures for software development and their enforcement were accorded a lower priority.

The software is unnecessarily complex

The AFOS software is complex and tightly integrated with the telecommunications and hardware operating system. Of necessity the software must have some complexity, but due to hardware and operating system limitations, the software is much more complex than it needs to be.

Software is normally developed in independent modules which are tied to other modules with a limited number of interconnections. The point of interconnection between two modules is called an execution path; it designates the order in which the software performs a set of instructions. Modules are designed to be independent with very few interconnections so that changes in one module do not cause changes in other modules. Also, the use of independent modules greatly increases the ease of isolating problems and program errors.

However, to resolve operating system and capacity problems, AFOS programers used a highly integrated software design to conserve core memory and designed software modules to perform multiple functions. They also closely linked the major software

subsystems (that is, communications, data storage and retrieval, and message composition). Thus, the AFOS software is composed of subsystems made up of highly interdependent software modules. Consequently, the NWS programing staff has experienced problems when modifying one module or subsystem. Because of these flaws in the software design, it is most difficult to avoid problems with other parts of the system.

Because the original operating system did not meet AFOS requirements, the NWS programing staff significantly modified the vendor's operating system to make it more compliant. However, these modifications have also greatly increased the system's complexity, which contributed to reliability problems.

AFOS consists of four major subsystems made up of over 300 closely linked software modules. The NWS programing staff estimates that when the software system is operating, it has millions of potential execution paths. With this number of modules and potential execution paths, tracking software routines and tasks to resolve software problems is difficult and costly.

The complexity of the software has created numerous unsolved deficiencies that affect all major subsystems. Foremost among these deficiencies is the deadlock problem. The system experiences deadlock when the computer attempts to process two or more tasks that need the same resources. This condition makes the computer incapable of processing other tasks, and therefore the system malfunctions. Because the computer is processing data from many sources simultaneously, the problem occurs frequently and unpredictably.

Other software problems include the following:

--When more than one forecaster at a site uses the system, the data retrieval and manipulation routines fail.

--Of the four major software backup routines, only one works reliably, but with extensive use it causes the data storage subsystem to malfunction.

--When the message composition subsystem fails while a forecaster is preparing a forecast, the prepared message is frequently lost. The forecaster must then rewrite the forecast.

NWS' attempts to correct software problems

NWS has adopted numerous approaches in trying to solve the software deficiencies, but they are so integrated with the hardware capacity and operating system problems that solutions applied to date have been inadequate. In February 1981, following a 2-month assessment of the system, NWS concluded that:

--The AFOS software is unable to meet NWS' operational requirements.

--The software as developed does not provide an adequate basis for continuing development.

--Any further software development would not be cost effective and probably would not result in significant improvements.

## NWS DID NOT ADEQUATELY USE STANDARD SOFTWARE DEVELOPMENT PROCEDURES

NWS did not follow standard software development procedures established by the National Bureau of Standards for Federal agencies to ensure the development of quality, documented systems that meet user needs and are efficient and cost effective. For example, NWS did not (1) adequately identify and freeze the system's functional requirements, (2) prepare design specifications, (3) implement a change control process, (4) develop the system as independent modules, (5) document the system, and (6) develop a comprehensive testing program.

As a result of not adhering to these procedures, NWS programers developed the software system without a clear understanding of its performance requirements. The resulting system is poorly understood by the programers responsible for its development and is for all practical purposes completely undocumented. In addition, the subsystems are so interdependent that attempts to improve the software often result in unanticipated problems elsewhere in the system. To resolve these new problems, further system refinements are required that in turn may introduce new software problems. As a result, the development has been time consuming and costly and has produced software that does not work. These problems could have been avoided or mitigated by rigorously utilizing standard software development procedures.

### Requirements were not defined and frozen

Functional requirements identify the work a software system is intended to perform and detail specific interrelationships among the system's separate parts. When these requirements have not been properly defined, the software designers are hampered in developing software because they do not have an adequate basis to compare their results against needs. The developing organization will experience difficulties in managing the development process because the resources and time needed to accomplish the total task cannot be determined. Further, it becomes difficult to establish milestones because there is no assurance that development estimates are reasonable.

NWS has neither adequately identified nor frozen system requirements. The system requirements have been significantly changed since the project was initiated in 1974. From 1974 to 1978, users identified new requirements and enhanced capabilities that were subsequently incorporated into the system. Since 1978, the developers have been reducing system capability in an effort

to achieve a stable system. In effect, NWS is now removing much of the software it has spent the last few years developing.

As a result of NWS' changing requirements, two problems have occurred.

--Completed development work had to be redone because of design changes.

--The system designers have been unable to effectively develop the system because it is continually changing.

This situation occurred primarily because NWS initially believed that the system had more than adequate capacity. As a result, management believed it could respond to the needs of the field and included desired enhancements.

AFOS lacked adequate design specifications and a change control process

A primary component of the development process is software design specifications. Design specifications translate requirements into the detailed guidance needed by the programers. In addition, these specifications provide a system overview that permits an assessment of whether the design is feasible or desirable in relation to the total system objectives.

Specifications detail what each part of the system will do and help manage the development in three ways. First, the specifications provide a system overview of all planned capabilities for management analysis. Second, by comparing progress against plans, managers can monitor development. Third, the design specifications provide a baseline for testing.

After developing design specifications, the organization should enforce a change control process. Basically, this process ensures that any change is thoroughly analyzed with respect to both specific and overall system requirements. Further, this control process should limit changes to the absolute minimum.

NWS developed AFOS without the benefit of either software design specifications or an adequate change control process. Consequently, programers prepared computer programs directly from functional requirements documents. Information from these documents is inadequate because they lack the specifics required to write computer programs.

As a result of not developing specifications and implementing a change control process, NWS lost control of the development process. Specifically:

--Programers determined independently what programs to develop and what functions the programs would contain.

--AFOS developers do not have sufficient knowledge of what the program modules contain and how they work.

NWS did not recognize the need for relatively precise design specifications. NWS understands very well what AFOS is to do; this understanding, however, is limited to a knowledge of the desired end result. NWS does not know in specific terms how the system is to perform these functions. For example, NWS wants all information available to field offices within minutes of the information entering the system. This general knowledge, however, in terms of the way the system meets the need, requires hundreds or thousands of detailed interactions between software modules in different subsystems. Precise design specifications are important because an ADP system's software will usually undergo almost continuous modification and change. The programer making these changes must clearly, fully, and accurately understand the system. Without design specifications, this knowledge cannot be achieved.

In a 1981 software technical assessment, NWS concluded that further development, no matter what level of resources are expended, may not produce significant software improvements. 1/ This is the basis of NWS' conclusion that the software must be completely rewritten. The lack of design specifications is a key reason for that assessment.

Lack of documentation

Documentation is a detailed set of procedures which explains what the program does, how it performs the function, how the program interacts with other programs, and other information. This documentation must be kept current to make it possible to modify or maintain the program following the software development phase. Documentation also includes instructions and procedures for those operating the system, such as forecasters at field sites. This documentation helps in training personnel to operate AFOS and helps the operator resume normal operations following system failures.

Documentation is absolutely critical to effective software development and operation. Without adequate documentation, development, maintenance, and enhancement become difficult, if not impossible. In developing AFOS, NWS did not develop and

---

1/The NWS assessment that further software development may not produce improvements is based primarily on the lack of documentation and modularity in the original design. Because of these two problems, further development may produce unintended side effects which make the software worse, not better. The only way to resolve these two problems is by completely redeveloping the software using a modular design and documenting the new software. This is in essence a complete software redevelopment effort.

enforce documentation standards and procedures. As a result, documentation was not prepared, and NWS to date has been unable to prepare documentation after the fact.

In 1979 NWS initiated a 90-day effort to document the system. NWS program officials acknowledged, and we concur, that this effort produced unsatisfactory results that at best provide a high-level system overview. The documentation is not an adequate base for system reviews, assessment, or development. Because of the size of the project and the loss of key personnel, NWS, in our opinion, cannot adequately document the system on a catchup basis. As a result, NWS cannot completely understand the contents of several hundred thousand lines of computer program code.

This deficiency occurred because NWS initially believed the software development effort was a task which could be quickly accomplished. This belief is demonstrated by the insufficient time initially scheduled for software development. Had NWS recognized the magnitude of the task and the time required (4 years), we believe it would have placed greater emphasis on documentation.

During our review NWS initiated action to document selected segments of AFOS' software by obtaining the services of an outside contractor. As of October 1981, this material was not available for review. Therefore, we are not in a position to comment on the adequacy of the documentation under development. However, it has generally been the case that after-the-fact documentation has been of limited value.

Inadequate software testing

Without a carefully controlled and thorough test program, management has little assurance that the system will meet user needs. Further, management loses a critical checkpoint for identifying and correcting system problems and minimizing project slippages. An adequate test program requires

--an independent testing team with sufficient authority to develop and enforce test procedures,

--an adequate staff with training and experience in ADP system testing,

--program and design specifications which include objectives and measurable performance goals, and

--a realistic and appropriate test methodology.

The NWS testing program lacked all of these requirements. The testing team had limited authority, had minimal experience with ADP systems, was assigned part time to testing, and had such

limited resources that it was unable to effectively carry out its tasks. The team tested known problems on a pass/fail basis. If the program would execute, it was good; if not, it was deficient. The testers and developers lacked program specifications showing the functions a module or subsystem should perform and how it fitted into the total system. Without this performance criteria, test teams can only use an empirical methodology (try it and see what it does).

Empirical methodologies are not considered appropriate for system testing because they do not provide information on how the program operates and its effect on other programs. As a result, this approach provides inadequate information to serve as a base for further system development. The approach severely reduced the value of the limited tests performed.

The NWS test manager was assigned two part-time staff members to perform all AFOS testing. The team had minimal experience with ADP testing and lacked the training required for this function. Due to its size and complexity, AFOS required a large, full-time staff for an adequate test program. The test team should have had experience and knowledge in designing (1) telecommunications, (2) software, (3) hardware, (4) operating systems, and (5) software testing methodologies.

## NWS SHOULD CONTRACT FOR SOFTWARE DEVELOPMENT

NWS is an operational organization which normally is not involved in developing major software projects. As a result, NWS as part of its normal business does not require personnel trained and experienced in the various disciplines required by software projects. In addition, as the Director of NWS has repeatedly pointed out, NWS staff resources are stretched extremely thin even for meeting normal organizational requirements.

Major software projects such as AFOS require hundreds of staff years of developmental work. Because this work is done infrequently, organizations normally lack the in-house personnel to develop their own systems. As a result, it is normal to contract out the development with the agency retaining oversight, management, and approval responsibilities. Because NWS underestimated the magnitude of AFOS development and wanted to hold costs to the minimum, it decided to develop AFOS in-house. This severely strained NWS resources.

The Director of NWS indicated that in developing a new system to replace AFOS, greater reliance, where appropriate, would be placed on contracting development. We believe that contracting out large software efforts in the future will relieve staffing constraints and should result in higher quality products because the work will be performed by full-time, experienced ADP development personnel.

## CONCLUSIONS

The applications software developed for AFOS has serious problems which can be resolved only by a significant redesign and redevelopment effort. In developing the software, NWS failed to follow standard procedures. This deficiency was particularly evident in the areas of documentation and program testing.

As we have previously reported to the Congress, development and maintenance of applications software for the Government is frequently not effective because management practices generally accepted in the information systems profession are not usually followed. Agencies frequently do not prepare requirements analyses, cost-benefit studies, or comprehensive project plans, nor are full-time project managers with authority, responsibility, and accountability always assigned to software projects.

NWS' problems with software development were, in part, caused by a lack of initial understanding of the project size and complexity. As a result, NWS performed work in-house beyond its staffing and experience capability. The software development effort should have been contracted out, and NWS should have hired staff members with the required training and experience.

## RECOMMENDATIONS

We recommend that the Secretary of Commerce direct NWS to

--adhere to standard software development practices in completing AFOS and in developing a new system and

--fully document the AFOS software to meet the needs of the developing staff and operating personnel.

## AGENCY COMMENTS AND OUR EVALUATION

NWS stated that AFOS software meets all essential requirements for field use and the original objectives as listed in the AFOS Program Development Plan and subsequently determined by interaction with operational personnel. However, AFOS does not meet a number of NWS' initial requirements prepared in 1974. Nor does it meet the updated requirements study completed in 1980, which stated the following system specifications for AFOS software: (1) it should be developed in a modular way to allow ready modifications and/or expansion of individual software functions, (2) it should be expandable not only to permit an increase in the number of communication lines and peripheral equipment being serviced but also to allow for an increase in the number and types of software functions under development, as well as data from the automated

meteorological observation system, and (3) to be reliable the software should not malfunction more than once a year. 1/

NWS stated that the software capability has been reduced in an attempt to meet the specifications for a reliable and stable software system. Moreover, NWS maintained that the software is currently performing satisfactorily and that the software design has been validated by a systematic NWS test program initiated in early 1980. Yet NWS agreed that AFOS software is complex and tightly integrated. We believe this deficiency is the fundamental flaw in the software, the cause of most other software deficiencies, and can be remedied only by a complete redesign. The tightly integrated software will be a problem to those who must design subsequent changes in AFOS, a factor NWS acknowledges. Further, AFOS is not expandable. For example, it cannot handle data from either the automated meteorological observation system or the radar system. In addition, the current reliability level of AFOS does not meet original requirements. In the March 1981 test of AFOS, the "best" weather station's system failed 5 times per day and the "worst" site experienced crashes 36 times in 1 day. With the increase in volume of activity and products throughout the nationwide system, coupled with the unreliable and untested system segments, AFOS is not likely to meet the specifications of one malfunction per year and may be unable to meet the August-September test results of one to two times per day.

NWS' claim that software problems have been corrected and that AFOS software works satisfactorily is not well founded. The magnitude and gravity of identified deficiencies cannot be corrected without extensive and costly modifications and a series of exhaustive tests. In particular, the operating system is not capable of meeting the requirements of the radar and satellite systems. In short, the AFOS software has been improved to the point where it can automate the functions provided by the current system. The software remains incapable of meeting the new, more advanced features it was intended to provide.

---

1/NWS' original specification that the AFOS software should not fail more than once a year was identified in NWS' minimum requirements document for AFOS. This goal is unrealistic considering the state of today's technology. We also agree with NWS' current contention that AFOS can fail more frequently than one time a year without disrupting operations. In its August-September 1981, validation test, AFOS software failed on an average of one to two times per day at each field site. This was a considerable improvement from March 1981 when the software failed from 5 to 32 times per day at each site. We continue to have reservations about the current failure rate of one to two times per day.

Essentially, NWS divided its management of AFOS into two phases: (1) original development work occurring from about 1974 to mid-1979 and (2) mid-1979 to the present. During the first phase NWS described its management approach as being an "iterative process." NWS explained that it had difficulty determining user requirements because forecasters follow variable forecasting procedures and are generally unfamiliar with ADP. Therefore, NWS employed an iterative process to capture and define the more subtle software requirements. NWS claims that despite earlier problems, this process resulted in an effective system now in actual field use which satisfactorily performs essential tasks reliably and rapidly. NWS noted that this process often yields the most satisfactory systems performance. We agree that an iterative process can be useful and even successful. However, an effective iterative process must be planned and followed as such. We found no evidence in NWS planning documents that an iterative process was intended when AFOS development started, or is anything more than an after-the-fact explanation.

The second management phase began when NWS management determined that the developers were having technical difficulty in developing and testing the system and there was a need to strengthen overall program management by initiating certain development disciplines. According to NWS, this strengthening included invoking a software change control process, adequately documenting the software, and reestablishing a test program.

NWS stated in its response that contractor personnel were used in AFOS development. NWS did hire a limited number of contract programers to work under the direction of NWS managers. However, this use of outside contractors was not adequate to address the significant burden placed on NWS personnel of developing AFOS in addition to their regular duties. We continue to believe that NWS should use contractors to perform technical work and concentrate NWS staff on project management.

NWS stated that improvements have been incorporated into AFOS and that improvements in performance and ease of software maintenance can be made in the future. We acknowledge the improvements in AFOS' performance, which were in part demonstrated during the August-September 1981 validation test. However, improvement in AFOS' reliability was obtained at the expense of deleting features already built into the system in order to reduce the strain on limited computer core memory. Most of the improvements in AFOS were the substitution of one capability for another. In addition, the improvements to AFOS have been limited to improving the system's ability to automate the functions performed by the current system. Future improvements to AFOS cannot be made to the extent that NWS stated in its response because AFOS software, as NWS noted, is not modular in construction. If AFOS is to be significantly improved, the system's component parts (hardware, software, and telecommunications) must be replaced entirely. We therefore continue to have major reservations about

NWS' intention to implement AFOS nationwide before a comprehensive reappraisal is made.

NWS' comments are summarized in appendix I and presented in their entirety in appendix II.

## CHAPTER 5

## THE AFOS TELECOMMUNICATIONS SYSTEM IS INADEQUATE

The telecommunications system that is an integral part of AFOS performs very important functions. It handles the entry of information into AFOS, the removal and storage of information, and the transmission of information in the system. Since AFOS handles communications between more than 200 NWS field offices, the FAA, the Air Force, the Navy, and the NMC, and must do so in a highly reliable manner, these functions are critical. Additionally, the telecommunications system must be flexible so that other systems currently under development by NWS, such as remote area meteorological observing stations and satellite and radar data, can be incorporated.

We found, however, that the AFOS telecommunications system is unreliable, inflexible, and expensive to operate because of inappropriate design and poor software. NWS is aware of these problems and intends to design a new telecommunications system as part of its complete new system but feels the current design will support AFOS operations.

### THE AFOS TELECOMMUNICATIONS DESIGN

A reliable telecommunications system consists of two basic components: first, a telecommunications design, which encompasses how the information is sent (satellite or cable) and how the various users are connected (each office connected directly to a central office or all offices connected in a circuit); and second, communications software, which sends, receives, and stores the information in the minicomputer at each office.

The telecommunications design that NWS selected for AFOS is known as a loop. In this design, WSFOs in each of NWS' four regions are connected in a circuit and information passes in both directions around this circuit to every WSFO. All four regional loops and the NMC are connected at the SMCC. WSOs are connected to their "parent" WSFO by direct communication lines similar to spokes in a wheel. This type of communications design is called a star.

The telecommunications software is modified specifically for each office to perform various functions. Individual modifications are made because each office has different requirements for information. All weather information passes around the loop, and each office must extract the information it needs to support users in its specific area. Additionally, field offices must in turn relay information to other users, such as private meteorologists.

Additionally, because NWS shares weather information with other services, a central communications office that exchanges this information is required. The System Monitoring and

Coordination Center, designed for this purpose, also monitors the entire telecommunications network to ascertain its status and helps offices to replenish their information bases in the event of a computer failure.

## AFOS telecommunications design is unreliable

The AFOS loop telecommunications design is unreliable because a failure at any station in the loop affects every other station. Therefore, overall loop reliability depends on the number of stations. Reducing the number of stations on a loop circuit increases overall reliability. The original AFOS telecommunications design connected all WSFOs in one large national loop. This design was changed into four smaller regional loops to increase reliability and allow better system management.

An additional factor contributing to the low reliability of loops is their unsuitability for a nationwide common-carrier system like AFOS. One leading telecommunications consultant described loops and their disadvantages as follows:

> "Major disadvantages of loops are their relatively inferior reliability and response time properties when connecting large numbers of terminals at traditional common carrier speeds."
>
> * * * * *
>
> "Loops are useful in limited distance applications where many individual terminal locations must be connected in a relatively small geographical area."

This design was selected because NWS emphasized communication line costs to the exclusion of other operational factors and characteristics. An advantage of loops is that they are one of the cheapest forms of telecommunications. However, the selection has proven to be a false economy.

NWS has added several features in an attempt to offset the inherent reliability problems of the loop architecture; however, each of these features creates an additional workload, increases system complexity, and compounds the chance for further errors. The workload imposed by these added features may be counterproductive because AFOS is at times very heavily loaded, which may result in further system instability.

## AFOS telecommunications software has problems

An important part of the telecommunications system is the communications software in the various AFOS minicomputers. This software controls the flow and storage of messages at field sites.

Normally, the communications software is designed as an independent module so that changes to the operating system and applications software do not affect, or require modifications to, the communications software. This is especially important in a system like AFOS which anticipates many changes, such as the addition of new capabilities. However, the AFOS communications software was closely coupled with the other software in an effort to conserve core memory. NWS' failure to design it as an independent module not only limits the system's flexibility but makes the identification, isolation, and correction of faults difficult because changes in one software system will often have unknown effects on the other software systems.

Because of this inflexibility, new capabilities cannot easily be added to the system. These capabilities, made possible by advances in technology and changing user requirements, are expected to be substantial in the next decade. An NWS study team in a January 1980 study 1/ analyzed these new requirements and ways that NWS could reorganize to meet them. The study concluded that NWS would have to rely increasingly on automating weather observations and warning dissemination. This automation not only involves current manual observations but also increases the use of remote sensing, from the ground and satellites, of the oceans and the upper atmosphere. Remote sensing greatly increases the data available, its timeliness, and the accuracy of forecasts. Automating these observations would free personnel for new tasks. However, incorporating these capabilities is dependent on a flexible communications system, currently nonexistent in NWS.

The telecommunications software has other problems.

--The software is incapable of transmitting data to private meteorologists and other users of NWS forecasts and observations and cannot be modified to perform this function.

--Some of the backup capability for use in emergencies has been removed.

--Three systems that should be able to interface with AFOS beginning in 1985 cannot be added to the system.

--The use of these systems, which are currently under development, is dependent on their being tied in with AFOS. (See ch. 7.)

## TELECOMMUNICATIONS SYSTEM DOES NOT MATCH ORGANIZATIONAL PHILOSOPHY

The loop structure of the AFOS telecommunications system conflicts with NWS' decentralized management practice and

---

1/"A Proposal for the National Weather Service Field Organization in the 1980's."

philosophy. NWS field offices are intended to exercise a great deal of flexibility and independence to meet local needs; the actions of one office have little effect on others. The loop architecture, however, makes field offices dependent on one another in a way that causes system problems at one station to have an extremely adverse effect on other stations. For example, if one station does not take corrective action following a software malfunction, a number of stations can completely malfunction. This condition has frequently occurred in the past. In a few cases almost an entire regional loop has been shut down because of a malfunction at one site. To maintain the loop architecture operationally requires highly standardized procedures and a strong enforcement policy. Because NWS is not organized to manage a high level of interdependence and does not wish to impose the level of system discipline required to make the system work, organizational conflicts are created.

## TELECOMMUNICATIONS REQUIRES SUBSTANTIAL SUPPORT

The telecommunications system requires a high level of manual intervention to operate, for two reasons. First, inadequate hardware capacity and software stability problems forced NWS to abandon many of the planned automatic features. Second, low reliability and system complexity forced officials to assign a full-time individual to monitor the system at every field office in which AFOS is installed.

Because of the high degree of interdependence of stations on the loop, failure of a communications line or station is of critical importance, and therefore a number of recovery features were planned for AFOS. They were of two types, automatic and manual. Automatic features included dialing a communications line to replace a failed line. NWS has been forced to remove most of the automatic backup features, thus requiring greater manual intervention for failure recovery than planned. For example, if a station on a loop fails, the failure must be fixed within 10 minutes or a bypass switch must be manually thrown to cut the site out of the loop. Failure to do so can cause data to be lost and can create failures in adjoining stations.

The designers of AFOS assumed the system would be so stable that it would practically run itself without manual intervention. Based on this assumption, NWS did not initially give operators needed training in diagnosing problems and procedures to effect recovery. Because of reliability problems, NWS' assumptions about the system running itself have been inaccurate. The system requires a very knowledgeable and experienced person to work on it full time at every office to maintain operations at an acceptable level.

## SYSTEM MONITORING AND COORDINATION CENTER HAS MANY PROBLEMS

Since the SMCC is the heart of AFOS communications, the overall quality of communications support is completely dependent on this unit's operation. All four regional loops and the NMC are connected here. Information from all sources flowing to and from the NMC passes through the SMCC, including information exchanged with the other weather services (FAA, Air Force, and Navy). In addition, the SMCC monitors the status of all offices in the system and helps them reestablish their data bases following system failures.

NWS has been working on making the SMCC operational but it still has many problems. These problems occurred because NWS seriously underestimated the resources needed. Problems such as insufficient equipment, inadequate software, and lack of monitoring have led to cancellation of planned tests, inability to support malfunctioning sites, and serious concerns about the system's ability to support all four regional loops if AFOS becomes fully operational.

NWS originally expected that the SMCC would need only two minicomputers. The SMCC now has 12 AFOS minicomputers. More may be needed because the workload and number of minicomputers are largely dependent on the telecommunications system's reliability. The lower the reliability, the more stations that must be supported because of communications failures.

SMCC software, originally developed by modifying the standard WSFO software, also has problems. This software was not designed for and does a poor job of meeting the SMCC's requirements. For example, the SMCC software was not designed to perform system monitoring, build a data base on system malfunctions, readily support the SMCC functions of data base backup and replenishment, and act as a remote support for malfunctioning sites. This condition contributes to the SMCC's current instability. The SMCC software still will not adequately perform many functions necessary for the system to be used operationally.

A particularly important function that NWS initially neglected is the SMCC's monitoring function. This function should notify personnel of malfunctions so that corrective action can be taken and a historical record of events can be built for planning purposes. Recent network tests have shown the importance of monitoring and that the SMCC lacks this fundamental capability. Because these functions were assigned a low priority, AFOS project managers did not provide adequate staff to develop them.

NWS assigned the SMCC a low priority because the original assumptions in developing the system included a high level of system reliability. Had this reliability been achieved, the SMCC's monitoring function would not have been as important as it has become.

Concerning the SMCC, in March 1981 NWS stated:

"Among the largest remaining uncertainties about the AFOS system are the adequacy of the design and performance of the SMCC. The questions are compounded by the increased demands of full national operations with four regional loops, several spurs, network monitoring and backup functions. * * * It is clear that a carefully planned effort, probably substantial, is required before a sufficient level of confidence in the readiness of SMCC can be achieved."

## THE NEED FOR TELECOMMUNICATIONS ALTERNATIVES

NWS recognizes the importance of a reliable telecommunications system. Following tests conducted in January 1981, NWS program developers reported to management that:

"The communication system must be made more reliable. The high rate of line failures must be eliminated and the source of communications deficiencies that cause AFOS crashes must be found and corrected. * * * Failure to solve it will cause AFOS to fail."

* * * * *

"The communications design is deficient in that a station may destroy loop integrity by merely failing to go into by-pass during periods of computer outage. This is compounded by the inability of SMCC to know what stations are causing this problem."

NWS has acknowledged that the system places "added demands for network monitoring and management discipline, configuration control, and orchestrated implementation of changes." Further, because of the importance of telecommunications for meeting current and future needs, NWS intends to replace the telecommunications system as part of its new system development.

NWS now acknowledges that the loop architecture is not a viable long-term approach and has contracted with a consulting firm for a comprehensive analysis of potential alternatives for use in the new system. This analysis also includes the potential impact of requirements outside AFOS, as well as the management implications of alternatives. The first part of this analysis has been completed. The consulting firm has made the following points about any future telecommunications architecture:

--It must be very flexible to expand and contract with future needs. This flexibility is especially important because firm data on future requirements is lacking.

--It is critical that the architecture selected require minimal management involvement.

## CONCLUSIONS

The AFOS telecommunications system is not appropriate for meeting NWS' needs. It requires extensive and costly onsite staff support. The system is inflexible and unreliable and conflicts with NWS' organizational philosophy. The telecommunications system will need to be completely replaced, and in replacing the loop system, NWS should adopt an alternative which is compatible with its organizational structure.

NWS' decision to use the loop approach was based on a desire to hold the system's cost to a minimum. Reliability in telecommunications is closely related to cost. Loops are one of, if not the least expensive form of telecommunications in terms of pure communications cost. However, the tradeoff is lower reliability and less flexibility.

## RECOMMENDATION

We recommend that the Secretary of Commerce direct NWS to replace the current telecommunications system as part of its development of a new system.

## AGENCY COMMENTS AND OUR EVALUATION

NWS stated that the telecommunications system is flexible and reliable and that it does not require a high level of manual intervention because of unstable software and inadequate hardware memory capacity.

It is important to note that a 1980 assessment of the AFOS loop architecture disclosed that the reliability of the AFOS telecommunications system continues to be a major problem. Further, a March 1981 test of AFOS showed that system performance was poor and that AFOS was inadequate for operational use. It did not perform according to specifications, and it does not meet the agency's overall requirements. NWS is currently evaluating alternatives and has indicated that it plans to develop a replacement telecommunications architecture as part of a new system.

NWS disagreed that AFOS requires a high level of personnel support. NWS used an inappropriate measure--the actual time to deal with a specific problem--as the basis for the statement. This measure is only part of the calculation of overall support staff needs. At each site, at least 50 percent of one person's time is devoted to training personnel to resolve technical problems. This is a high level of investment in such resources. NWS has established a new software diagnostic course for AFOS maintenance personnel, primarily so that they can diagnose the cause of software crashes. NWS has established AFOS coordination groups of about 10 full-time people in each region.

Operating AFOS requires many more people than are required to operate and maintain the current system. This became evident as NWS added 119 positions for the AFOS project. NWS contends that AFOS has resulted in over 200 fewer positions to support the NOAA Weather Wire Service. This NWS statement is misleading because it refers to authorized personnel ceilings, which have never been filled, and not to people on NWS' payroll. In fact, NWS has been supporting the Weather Wire Service without these positions for years using the current system, not AFOS.

NWS should continue examining the need to replace the AFOS telecommunications system as part of the new system proposed for development. A new telecommunications system would provide capability that the agency requires but cannot receive from the current loop architecture because of design and operational limitations. Further, a new telecommunications system would improve reliability and minimize failures in the telecommunications network, which is crucial to the operation of the total system. More recent tests have shown improvements, but NWS recognizes the limitations of loops and is studying alternative systems.

NWS also stated that the SMCC is adequately performing its functions. We note that NWS has apparently completed and is using network monitoring software at the SMCC. We have not verified or reviewed this information but believe it is accurate. This improvement should help NWS to monitor the AFOS network and should be of considerable assistance to the SMCC. However, since only selected segments of the SMCC functions and associated software have been tested, untested segments remain. NWS has little or no assurance that they meet requirements. Tests of the SMCC's software in terms of a fully loaded system would be necessary to assure system stability. Further, in performing its monitoring function, the SMCC must demonstrate its ability to adequately respond to system failures along the telecommunications network. Before AFOS is implemented, the SMCC operation and associated functions demand the successful completion of comprehensive tests.

NWS' comments are summarized in appendix I and presented in their entirety in appendix II.

## CHAPTER 6

## THE AFOS HARDWARE NEEDS TO BE REPLACED

The hardware in the AFOS system includes 310 minicomputers. Each WSFO has two minicomputers so that if one fails, the other can provide backup. Each WSO in the AFOS network has one minicomputer. In addition to minicomputers, each field office has a variable number of work stations for meteorologists. Also included is a control console for maintaining the operation of the station's equipment. The operation of this hardware and the functions it performs are controlled by the operating system, a software component. The operating system is critical to the effective use of the system and controls the functions of all hardware components.

NWS has experienced serious problems with the operation and maintenance of its computers, the system's hardware, and the operating system. Further, the hardware does not adequately meet agency requirements. We are also concerned that NWS' logistics program for maintaining spare parts may not be adequate to support a fully operational system.

### AFOS HARDWARE HAS PROBLEMS

Two major problems prevent the hardware from meeting NWS' requirements. First, the performance of the hardware's operating system falls far short of its intended role in directing and controlling the computer. Second, the hardware has inadequate core memory capacity to store software and forecast data. In our opinion, correcting these problems of the current computers would not be cost effective. As a result, NWS should replace the hardware as part of a redesign and development effort.

#### Operating system is inadequate

An operating system is highly specialized software developed by the system's manufacturer. It enables the hardware and applications software to work together in accomplishing user needs. The AFOS operating system controls each minicomputer's central processing unit. It is integral to the operation of the minicomputers and is required for operating the hardware. The AFOS operating system functions much like the human brain in that it controls the independent parts of the system and causes them to act as a unified whole. Because of the specialized experience required to develop operating systems, they are usually built and modified by equipment manufacturers or software vendors. As a rule, user organizations do not modify manufacturers' operating systems.

NWS requires an operating system which can concurrently perform a number of separate functions. The operating system acquired with the hardware is unable to perform these functions. When it purchased the AFOS minicomputers, NWS was aware of the

operating system's limitations. However, at the time of the purchase, minicomputer operating systems which met NWS' requirements were not available. Minicomputers were a relatively new product, and NWS believed the operating system could be modified to meet its needs.

It should be noted that NWS made every effort to obtain an appropriate operating system. NWS initially found a vendor who agreed to provide a minicomputer and develop an operating system to meet its needs. Unfortunately, the vendor was unable to provide it, and NWS decided to go with its second choice--the present minicomputer and operating system. NWS then modified the operating system to meet its requirements.

These modifications to the AFOS operating system were made contrary to the advice of independent contractors. Further, the changes were poorly documented and their effects not fully understood. The following problems have resulted from these modifications:

--Maintaining the minicomputers will be difficult and expensive.

--The system's complexity has been increased because the applications, telecommunications, and operating system software have been tightly integrated. When any one of these is modified, changes to the other two are often required. This situation increases software costs and greatly reduces flexibility in modifying AFOS.

--Hardware and software improvements made by the minicomputers' manufacturer cannot be incorporated into the system without considerable cost and effort.

NWS has been making a substantial effort to resolve the minicomputers' operating system deficiencies for several years without finding an adequate solution. Not only has it modified the operating system extensively, but it has continued its attempts to procure an operating system suitable for the current minicomputer. As time passes the operating system problem becomes more critical. For example, the computer's design will be 10 years old in 1984, the current target date for AFOS to be a fully operational system. Further, the original design of AFOS has not been updated to incorporate the significant technological advances that are available from the vendor that would help solve the system's problems and meet overall needs. Further, the cost of adding adequate capacity, redeveloping the applications and telecommunications software, and procuring a new operating system for 310 minicomputers would probably approach the cost of an entirely new system.

Hardware has limited capacity

NWS did not adequately determine its requirements for AFOS and as a result purchased hardware with inadequate core memory capacity. The specific amount of the shortage cannot be determined because NWS does not know (1) how much capacity it needs or (2) the current capacity of its hardware. NWS has concluded, however, that all available capacity is fully utilized. This shortage of capacity created problems during development of the system, and as a result:

--The AFOS software could not be developed as independent modules and had to be tightly integrated to conserve memory.

--The smaller field offices (WSOs) with extensive communication requirements have limited ability to perform onsite data processing, a planned capability of the system.

--Large field sites (WSFOs) lack sufficient capacity to support external users.

--Much of the system's disaster recovery and backup capability has been removed because of the core memory capacity problem.

--The system cannot be expanded to meet current and future needs without a costly addition of more storage capacity.

AFOS REPAIR COSTS ARE LIKELY TO BE EXCESSIVE

In addition to the minicomputers' performance problems, maintaining them will be difficult and costly. System maintenance costs will be higher than anticipated because NWS did not select an appropriate logistics approach to maintaining a spare parts inventory.

A hardware logistics program is usually implemented under two basic approaches: (1) buy all identical hardware systems and spare parts required for the system's entire life cycle or (2) buy enough parts to meet initial needs, but continually update and maintain all units to make them identical to the most current equipment the manufacturer is producing. NWS did not follow either approach. Instead, it bought identical new systems and the engineering drawings and specifications, as well as a limited inventory of spare parts, in the initial procurement. NWS planned to have spares made as needed to preserve the system's original specifications, rather than to update them. As a result, maintaining AFOS will be expensive, and the hardware cannot easily be updated to take advantage of new technology that would correct major computer deficiencies.

NWS' decision not to include ample spare parts with the original computer system purchase order has caused problems with the availability of critical parts. Since the manufacturer no longer makes many critical AFOS parts on a normal basis, special production runs for these parts will be required. In some cases NWS will need to find new subcontractors to produce parts that are no longer available from the original source. Because all parts must be produced on a special basis, NWS will be forced to pay a premium price. Further, the premium price and the number of needed spares are expected to increase significantly over time.

Because NWS did not follow the second approach of updating and maintaining the AFOS hardware to make it identical with the manufacturer's current equipment, AFOS' capability and effectiveness have been limited. Generally, computer manufacturers introduce enhancements in computers they currently produce that improve reliability and lower operating costs. The manufacturer of the AFOS computer made numerous improvements to the computer's memory boards and other computer components it currently builds. Ninety percent of these changes could be considered enhancements that could have significantly improved AFOS. Nonetheless, NWS has not been able to take advantage of these modifications and enhancements.

Modifying the AFOS hardware to include such enhancements and to make AFOS identical to the manufacturer's current equipment may not be feasible at this time. Because NWS has made many changes to its AFOS equipment and these changes are undocumented, NWS cannot determine with any degree of accuracy the extent to which AFOS equipment differs from the manufacturer's current equipment. Further, there is no assurance that the AFOS software will effectively and efficiently operate at the most current revision level of the equipment the manufacturer is currently producing.

NWS' difficulties in keeping up with the manufacturer's current revision level for its computers resulted in part from the prolonged delays in completing AFOS and the rapid pace of technological changes in minicomputers. If AFOS had been completed on schedule in 1979, all the hardware it needed might have been purchased by that date.

## NWS' MAINTENANCE AND LOGISTICS SYSTEM WILL NOT SUPPORT AFOS

NWS' present maintenance and logistics system may be unable to support AFOS when the system is fully operational. NWS has already encountered problems with insufficient spares, late deliveries of spares, and extensive repair time. Additionally, the NWS repair center has had hardware maintenance problems that were caused by vacant staff positions, lack of adequate tools, faulty automatic test equipment, inadequate software, and inadequate skills to maintain the test equipment.

A key to effective maintenance capability is the use of automatic test equipment. This equipment's purpose is to minimize repair time, which reduces the need for a large inventory of spare parts. However, the benefits of the test equipment have not been realized due to testing program errors and the inability to maintain the test equipment in good working order. The repair center estimates that 50 percent of the test programs are defective.

Many problems with logistics would not have occurred had the automatic test equipment functioned as planned. To hold down costs, NWS pared its spare parts inventory to the minimum. It believed that the test equipment, coupled with organizational flexibility, would save money and meet requirements for spare parts. This approach has held down costs, but because of test equipment problems, it may be unable to meet NWS' needs.

The problems NWS has experienced with its logistics and maintenance system could jeopardize full implementation of AFOS. For example, field offices have experienced outages of up to 12 days due to a single parts failure, resulting in severe reductions in service and an inability to meet mission needs.

## CONCLUSIONS

The AFOS hardware is inadequate for meeting NWS' requirements. The system's primary problems are insufficient computer capacity and an operating system lacking the required level of capability.

NWS and independent contractors have concluded that the operating system must be replaced, and NWS intends to do so as part of developing a new system. Replacing the operating system will require NWS to rewrite its application software and to obtain additional core memory for the computers. We believe the most cost-effective solution to these problems is a complete replacement of the computer hardware and its operating system.

The AFOS logistic support system is likely to encounter problems if AFOS is fully implemented. The primary logistics problem resulted from NWS' decision not to maintain the equipment at the manufacturer's current revision levels. In replacing the AFOS hardware, NWS should acquire equipment and an operating system at the most current level produced by the manufacturer and should maintain them at the manufacturer's current revision level.

## RECOMMENDATION

We recommend that the Secretary of Commerce direct NWS to replace the AFOS hardware as part of developing a new, more advanced system.

## AGENCY COMMENTS AND OUR EVALUATION

NWS objected to our recommendation that AFOS hardware be replaced as part of a complete system redesign and disagreed with our conclusion that the design and capabilities of the AFOS hardware and operating system are inadequate. NWS stated that the system has more than adequate capacity and that the hardware's operating system is completely satisfactory for NWS' needs.

In its comments NWS said it plans to purchase additional core memory for the AFOS hardware. Since memory is in fact the capacity lacking in AFOS hardware, it is inconsistent to state that the capacity is satisfactory and yet plan to purchase more memory. To further support the need for additional capacity, in March 1981 a major NWS evaluation of AFOS concluded that the system requires at least $4 million in additional core memory. Also, in 1981 the AFOS project manager concluded that a number of features needed to meet minimal operational requirements could not be added because of inadequate capacity. We contend that NWS should procure additional computer memory if AFOS is to be the primary system. This additional computer storage would relieve some of the strain on capacity.

This $4 million in added core memory capacity will improve only the system's ability to automate the functions provided by the current system. AFOS will remain unable to provide the additional services and performance improvements which were originally intended for the system. NWS is aware of this and is planning to develop a new system to provide this additional support.

In 1974, the NWS technical review team which approved the operating system purchased by NWS concluded that the operating system was inadequate. Since then NWS has contracted for a number of independent technical reviews which have concluded that the operating system is inadequate. In fact, NWS itself concluded in March 1981 that the AFOS operating system is inadequate and placed a top priority on developing, contracting for development of, or purchasing an operating system.

NWS stated that "the problems with the flow and availability of spare parts have been resolved. However, previous assessments of the system have shown significant problems with the spare parts replacement program." In the last year AFOS sites have been closed down for as long as 4 to 6 weeks because of a single parts failure. In an earlier test, one site had to remain in a degraded operation for over 48 hours due to the parts problem. This performance level was initially unacceptable for minimal operational needs, and such problems resulted in

NWS' curtailing AFOS' performance criteria. In this context, NWS has significantly increased the acceptable time allowed to repair faulty equipment and for a site's system to remain inoperative.

NWS' comments are summarized in appendix I and presented in their entirety in appendix II.

## CHAPTER 7

## ALTERNATIVE APPROACHES TO IMPLEMENTING AFOS

NWS agrees with our view that AFOS should eventually be replaced and intends to prepare a long-range plan for developing a new system. In the meantime, however, the agency plans to implement AFOS nationally on an "as is" basis to derive limited benefits from the work performed.

AFOS should not be implemented nationally without a thorough analysis of whether the system can produce benefits commensurate with its costs. AFOS should be required to undergo a major reappraisal before it is implemented on a national basis. This appraisal should include a study of relative benefits and costs as well as additional operational testing. We recommend such an appraisal because of evidence that the system as designed does not meet NWS' original performance requirements, will be expensive to maintain and operate, and will ultimately have to be replaced by a new system because of its limited capabilities.

An alternative to full implementation of AFOS is to concentrate resources on designing and developing a new system, using currently available off-the-shelf technology, that will come closer to meeting NWS' needs.

### CURRENT NWS PLANS

Following a detailed technical review of AFOS, NWS concluded in March 1981 that the possibility exists that the AFOS system is not viable. 1/ NWS decided to correct a number of identified system problems and to conduct an AFOS validation and demonstration test in August-September 1981. The results of this test would determine whether NWS would proceed to implement AFOS nationwide or discontinue all use of the system.

NWS conducted the AFOS validation test as scheduled and determined that the results were sufficiently positive to justify proceeding with national implementation of the system. NWS currently plans to implement AFOS by the end of 1982 in all four contiguous U.S. regions. This plan calls for leaving the current system in place until 1984 as a backup to AFOS in the event of system failures.

In implementing AFOS, NWS plans to freeze the system's software and operating procedures to the greatest extent possible. NWS has stressed that all changes to the system would be minor and would be made in the most controlled manner possible. This approach should help stabilize the AFOS system. NWS also

---

1/NWS Director's memorandum to regional and office directors regarding "AFOS National Implementation Decision," March 19, 1981.

plans to purchase additional core memory for the system at a cost of about $4 million.

NWS has also initiated plans for a new system to replace AFOS. This system, if approved and funded by the Congress, would be completed around 1989. NWS currently intends to develop the new system based on a new design rather than the AFOS design. The NWS decision to develop the new system totally apart from AFOS reflects a broader decision to defer correcting a number of AFOS' technical deficiencies. The new system is intended to replace the current communications as well as AFOS.

## NWS' EFFORTS TO ADDRESS AFOS' LIMITATIONS

NWS has addressed AFOS' limitations by correcting problems in ways that produce short-term solutions rather than long-term improvements that would assure effective and efficient operations over the next 8 to 10 years. Results from various AFOS operational tests, including the most recent test, indicate that AFOS' limitations affecting the long term will continue because of inherent design constraints that preclude it from meeting the agency's requirements. For instance, to meet changing requirements over the next several years, the AFOS system must be flexible to the extent that its hardware, software, and telecommunications components can be effectively and efficiently modified.

Interim steps to purchase additional core memory and to upgrade the AFOS telecommunications system, which is currently under assessment by a consultant, could increase flexibility. However, the system still would not have sufficient flexibility because of the constraints in the software for processing user applications and performing prescribed functions. The software design was not structured under a modular design concept; it was poorly documented and tested on a limited basis. The software limitations are essentially imbedded in the software design, and they preclude modifying the software effectively, economically, and efficiently. Consequently, this aspect of the software limits the flexibility of the entire system.

To increase the system's flexibility, NWS also attempted to modify the operating system. (This software executes, directs, and controls the computer system's hardware and system functions and processes.) This modification resulted in improved performance but did not succeed in increasing the flexibility to the extent required. Rather than taking further steps to address the problem of flexibility, NWS has now decided to forego software changes designed to increase flexibility by freezing all software design and development specifications. Freezing software essentially resolves the more immediate and critical problem of minimizing software malfunctions and system failures. Yet, freezing the design and halting basic design changes in software means that AFOS will continue to be an inflexible system, not capable of meeting prescribed requirements.

NWS' attempt to address another AFOS limitation--the capability of handling future programs and systems, such as the weather observing satellite program, the new weather radar systems, and automated weather observing systems currently under development--has not met with success. These programs are critically important for improving NWS' ability to forecast weather. AFOS' inability to meet future needs will become acute as the new radar and satellite systems become operational about 1985 to 1987.

Forecasting ability is often hindered by a lack of meteorological observations. Obtaining data from remote areas is difficult, and NWS forecasters must frequently do without this information. To help overcome this deficiency, NWS is currently conducting experiments in which automated weather observing systems are established in remote areas to automatically relay data to a minicomputer for analysis.

During our visit with NWS officials in charge of one of these projects, we noted that the project demonstrated the potential to save millions of dollars in the areas of improved water resource management and flood control. Thus, remote observation technology could bring about significant improvement in weather prediction and millions of dollars in savings to the public and industry. However, to translate this technology from an experimental to an operational state requires a communications system with the ability to receive and analyze this data. Because AFOS cannot handle these new systems now being developed, NWS' ability to realize the benefits of the new technologies will be significantly reduced.

## THE AFOS VALIDATION TEST

We monitored the August-September 1981 AFOS validation test. While we have reservations about the design of the test, addressed below, the following limited conclusions can be drawn from the test: (1) AFOS' performance has improved in the areas of stability, frequency of "crashes," user response time, and backup systems and (2) its ability to support the Weather Wire Service, a critical requirement, has also improved. Also, during the test we noted that AFOS operating personnel seemed more familiar with the system and better trained than they were in the spring of 1981 when we observed the earlier AFOS test. It appears that increased management involvement, NWS corrections to known SMCC problems, emphasis on standard operating procedures, and a significant increase in system discipline were largely responsible for the most recent improvements.

However, we did note a number of negative results. For example, the frequency of system failure has remained high in relation to NWS' original standards for reliability. But recovery procedures worked well, and the elapsed time to recover was less than that previously noted. Also, we observed that NWS performed minimal testing of certain features and functions believed to be the sources of potential problems. This limited

use of "troublesome" features would not be acceptable if AFOS were operational throughout the Nation and the system were fully loaded. Another concern was NWS' extensive use of personnel at all levels of management and staff during the test. This intensive support was maintained for a 2- to 4-week test and evaluation period, but it is unlikely that NWS could maintain this level of support on a day-to-day basis over the next several years of AFOS operation.

Test limitations

The AFOS validation test conducted by NWS in August-September 1981 had deficiencies in its design as well as in the results achieved. The results of this test therefore do not provide a sufficient basis for a decision to implement AFOS nationwide.

The test was limited in a number of respects. First, it tested AFOS' ability to handle only a small subset of major product categories--a few hundred of over 33,000 products AFOS is required to handle. Another major limitation was that the test did not provide results over a range of system load conditions. ("Load" refers to the volume of messages in the system, which normally reflects the number of users.) AFOS is very load sensitive, and its performance can degrade under a heavy workload. The AFOS test was generally performed under a light-to-moderate workload. As a result, the test did not measure the potential performance of the system in full operation. The test also excluded an appropriate standard for system failures. The number of system failures occurring per day exceeded the original standard.

Another limitation of the test was that it did not include full tests of "live" information as specified in two critical NWS requirements. According to AFOS specifications, the system must (1) deliver products from the SMCC to field offices, (2) transmit local meteorological observations to the SMCC, and (3) transmit this data from the SMCC to the FAA. During the test NWS attempted only limited transmission of live SMCC data to demonstrate SMCC's ability to send data to FAA. As a result, NWS has insufficient information to determine whether AFOS can adequately perform the required function of transmitting data to FAA. Demonstrating full performance of this feature should be critical to the final decision to either implement AFOS nationwide or discontinue its use, but NWS chose not to emphasize this capability in the test.

Moreover, insufficient information was collected during the test to enable projections of the costs and benefits of implementing AFOS at 200 weather stations nationwide. Because of the vast difference between the objectives of AFOS and the system's actual performance, cost-benefit information on its current operation is critical. In particular, NWS did not collect information on a major cost item, the personnel support required by AFOS.

In addition, the statistical evaluation method used for the AFOS test was deficient. ADP system tests are normally conducted at three levels: best case, worst case, and most probable. The AFOS' test plan called for conducting most of the test under the best or most probable case conditions. As a result, the test did not demonstrate whether the system could adequately perform under a worst case condition, thereby identifying needed corrections to system components. Also, the test did not demonstrate that the system can perform satisfactorily under a worst case method if implemented in 200 weather stations under fully loaded conditions. AFOS should adequately perform under a worst case assumption before it is considered for nationwide implementation.

## NEED FOR A MORE COMPREHENSIVE PLAN FOR MEETING ADP NEEDS

NWS continues to pursue two goals: implementing AFOS and concurrently developing a new system. NWS has not yet developed a detailed plan to carry out these objectives. Further, the NWS approach has not provided needed information, including a comprehensive strategy in support of such plans. For example, NWS' plans do not include a schedule to (1) further validate and test AFOS' performance, particularly for untested segments, (2) conduct a cost-benefit analysis of AFOS prior to full implementation, and (3) resolve the system design constraints.

A full test for AFOS should include measurement data to determine the effect on AFOS' performance of design deficiencies that are inherent in its hardware, software, and telecommunications components. By not focusing on the design issues, NWS is not in a position to estimate the effects of these deficiencies and/or evaluate the cost and reasonableness of correcting them. A full test should also provide information to determine the extent to which the software, hardware, and telecommunications are deficient and to what extent they are correctable. In addition, the test should address the overlapping and discrete functions to be performed by two systems in parallel--AFOS and the current communications system. Because both systems perform the same basic function of providing information to field offices and both systems will be operating in parallel for at least 3 years, AFOS should be tested in terms of this environment. The assessment should take into account other information, such as benefits and associated costs, that would be needed to conduct a cost-benefit analysis.

To adequately address the range of constraints, limitations, and problems involved, NWS should develop a comprehensive ADP plan that includes:

1. Both long-range and short-range approaches to data processing accompanied by strategies to carry out these plans.

2. An economic analysis that defines goals and objectives, formulates appropriate assumptions, identifies alternatives, and determines costs and benefits of identified alternatives.

3. An updated requirements analysis to reflect information needs that are consistent with agency mission and program objectives.

4. The impact of an advanced system development program on, and its relationship to, other agency systems and other relevant programs that involve satellite and radar imagery and local applications.

5. The application of new information technology that would overcome the deficiencies of the current AFOS design.

6. An assessment of the level of management involvement needed to effectively oversee and direct the various system development projects.

7. The appropriate organizational structure, including that of the project management office, needed for future systems projects.

8. The number and type of personnel required for three systems--the current system, AFOS, and the new system to be developed.

9. Results of various tests describing both positive and negative results with a description of corrective action required.

We believe that an NWS assessment of this information is a fundamental prerequisite to a decision whether to embark on national implementation of AFOS, as well as to begin a long-range effort to replace it.

## CONCLUSIONS

The AFOS system has inherent design problems which preclude it from adequately meeting NWS' needs. Because these design constraints are serious, AFOS is not, and is unlikely to be, a cost-effective or efficient system.

During the past several months NWS has made a concerted effort to correct some deficiencies and demonstrated during the August-September 1981 validation test that AFOS' performance is now improved. Based on our observations at various test sites and other test information, we concur that AFOS has been improved. These recent improvements indicate that AFOS has at least the capabilities of the current communications system operated for NWS by FAA.

2. An economic analysis that defines goals and objectives, formulates appropriate assumptions, identifies alternatives, and determines costs and benefits of identified alternatives.

3. An updated requirements analysis to reflect information needs that are consistent with agency mission and program objectives.

4. The impact of an advanced system development program on, and its relationship to, other agency systems and other relevant programs that involve satellite and radar imagery and local applications.

5. The application of new information technology that would overcome the deficiencies of the current AFOS design.

6. An assessment of the level of management involvement needed to effectively oversee and direct the various system development projects.

7. The appropriate organizational structure, including that of the project management office, needed for future systems projects.

8. The number and type of personnel required for three systems--the current system, AFOS, and the new system to be developed.

9. Results of various tests describing both positive and negative results with a description of corrective action required.

We believe that an NWS assessment of this information is a fundamental prerequisite to a decision whether to embark on national implementation of AFOS, as well as to begin a long-range effort to replace it.

## CONCLUSIONS

The AFOS system has inherent design problems which preclude it from adequately meeting NWS' needs. Because these design constraints are serious, AFOS is not, and is unlikely to be, a cost-effective or efficient system.

During the past several months NWS has made a concerted effort to correct some deficiencies and demonstrated during the August-September 1981 validation test that AFOS' performance is now improved. Based on our observations at various test sites and other test information, we concur that AFOS has been improved. These recent improvements indicate that AFOS has at least the capabilities of the current communications system operated for NWS by FAA.

In view of this demonstrated improvement in performance and the expenditure of about $100 million for the project, we conclude that NWS should be permitted to operate AFOS until 1989, but only if NWS completes a full economic assessment showing that interim implementation of AFOS for an 8-10 year period is cost effective. We emphasize that the recent AFOS validation test does not provide sufficient information for a final determination to implement AFOS nationally. Without further testing, analysis, and planning, NWS cannot determine the most effective course of action.

## RECOMMENDATIONS

We recommend that the Secretary of Commerce direct NWS to:

--Conduct a detailed cost-benefit analysis before deciding on full implementation.

--Conduct a test of the untested segments of AFOS before deciding to implement it nationwide.

## AGENCY COMMENTS AND OUR EVALUATION

NWS' response to our report was based on a draft version of this report, dated June 29, 1981. In that draft we suggested that NWS should immediately abandon the AFOS system. NWS disagreed with our position and believes that the existing AFOS system should be implemented nationally during fiscal year 1982 as the primary weather information system. As noted above, we no longer believe that AFOS should be abandoned. In this report we are recommending that national implementation be conditioned on a full assessment of AFOS and its alternatives.

In commenting on our June 29, 1981, draft report, NWS stated that AFOS meets or exceeds the original system requirements as specified in the June 1976 program development plan. NWS' reference to the 1976 document as the original requirement is misleading. The 1976 document referred to by NWS is a general overview description of AFOS. This document was prepared 2 years after the original specifications and is not a program specifications or requirements document. NWS developed a detailed set of program requirements in 1974 which became the basic design document for AFOS. AFOS still does not meet the NWS-developed specifications as cited in its original 1974 system requirements document. In fact, following its 1981 technical assessment, NWS itself noted that AFOS could not meet its original program specifications.

As a total project, AFOS was designed to accomplish two broad objectives: (1) automate the functions performed by the current system and (2) provide new capabilities to allow NWS to take advantage of improvements in meteorology. With the recent improvements made by NWS, it appears that AFOS will be able to meet the first objective--automating the current system. Further, AFOS has greater capability and capacity than the current communications system in terms of processing speeds, information

storage, and the ability to use computer programs and process data in field offices. However, AFOS cannot provide the new capabilities it was intended to deliver to its users. Therefore, delivery of the additional capabilities NWS requires will be delayed until a new system is developed to replace AFOS.

In response to our draft report and prior to the August-September 1981 validation test, NWS stated that AFOS had been tested and was fully capable of meeting "operational needs." However, in a January 1981 test of AFOS, the program test manager concluded that AFOS was unable to meet operational requirements. Based on the test, he stated that, "Because of the problems associated with using AFOS, most of the test monitors, operators and site managers felt that a severe weather incident would cause a total collapse of the AFOS operation." AFOS has not yet satisfactorily passed a complete system performance test under full load conditions, and until it shows it can do so, it is not feasible to state that AFOS is fully capable of meeting operational needs.

NWS system specifications state that before AFOS can become an operational system it must accomplish four essential tasks: (1) deliver data to the field offices, (2) permit the manipulation of data by the forecaster, (3) transmit information from the field office to the SMCC, and (4) deliver the field data from the SMCC to the FAA system. Currently NWS is using AFOS to accomplish only the first two tasks.

NWS stated that AFOS' backup system is perfectly acceptable, thoroughly tested, and meets all NWS requirements. The original design of AFOS had five system backups, and according to NWS specifications, all five are needed to meet the minimal requirements of an operational system. Of the five AFOS backup systems, two work poorly according to actual test results, two have been removed, and the remaining system has not been adequately tested. Therefore, the backup systems provide little assurance that AFOS can effectively meet its requirement for a reliable and stable system.

In its attempt to improve AFOS' reliability, NWS has conducted numerous tests of the field offices' ability to remain operational with only one computer instead of two. The assessment disclosed that normal operations at a field office cannot be supported by a single computer. Further, an independent contractor concluded that because of the system's design, one computer cannot satisfactorily maintain a site's system. We agree with this assessment.

NWS stated that it has corrected all the problems with AFOS and that the system now meets or exceeds all performance requirements. However, many of our observed problems with AFOS are inherent in its basic design and cannot be corrected in a period of a few months, if ever, short of replacing the entire system. Further, NWS did not attempt to correct any of the basic design

problems. As a result, NWS has not resolved and, as stated in its response, does not intend to resolve any of the design problems identified by us and by NWS technical staff. NWS plans to resolve the system's basic design problems by developing a new system, which could be completed by the late 1980's.

NWS plans to leave the current system in place as a backup to AFOS until 1984 to minimize service interruptions whenever AFOS fails to function. By this action AFOS will have been in parallel operation for about 5 years. This length of time to operate two systems in parallel is not in accordance with accepted management practices and strongly suggests that NWS still believes it needs more time to make essential improvements in the AFOS system. In Federal agencies and private industry a commonly accepted objective is to have systems in parallel operation for the shortest possible time. This approach is used because parallel operations are usually expensive, place a significant burden on operating staffs, disrupt operations, and delay effective use of the new system.

The NWS decision to continue parallel operations for an additional 3 years is indicative of AFOS' problems and supports our position that AFOS is not likely to become a fully operational system. We further contend that NWS will probably retain the current FAA system as backup until NWS develops a new system (scheduled for completion in 1989) or until FAA drops the current system, whichever occurs first.

Further, the overrun of 5 years for developing AFOS has extended the development period to 10 years. This 10-year development phase is twice the length of time the system will be in operation before it is completely replaced by a new system. A 2 to 1 ratio of a development phase to an operational time period is excessive and highly unusual. This analysis of years expended on development is based on the starting date of the development phase, which began in 1974. It is expected to end in 1984 when NWS plans to replace the current communications system. The 5-year figure for operations is that period between 1984 and the scheduled 1989 completion of the new system design and development phase.

NWS' comments are summarized in appendix I and presented in their entirety in appendix II.

## AGENCY RESPONSES AND OUR EVALUATION

After reviewing our draft report, NWS strongly disagreed with a substantial portion of it. (NWS' response is presented in its entirety as appendix II.) After analyzing its comments, we determined that NWS disagrees on 16 key issues.

This appendix focuses on these 16 issues and presents NWS' comments and our evaluations. We have also summarized NWS' comments and our evaluation in the digest and at the end of each chapter, as appropriate.

In reviewing NWS' comments to our report, we offer the following observations:

--Much of the material presented by NWS is primarily factual in nature. Generally, we have not taken exception to this information. However, we did not confirm its accuracy.

--NWS frequently stated in broad terms that information in our draft is either erroneous or trivial, but it provided no specific information or evidence to support its positions. We are therefore not in a position to respond to these points.

--NWS frequently summarized its overall concerns and disagreements with our report.

After observing NWS' August-September 1981 test of AFOS and based on preliminary test results, we modified our overall recommendation that NWS discontinue all use and development of AFOS. This required modifying our recommendations in chapters 4, 5, 6, and 7, which we have done. In essence, our modified recommendations acknowledge the recent improvements in performance and therefore provide a qualified "yes" for moving to the next step in the implementation of AFOS, which we suggest is to reappraise the new evidence of improvements in AFOS' performance.

In our opinion, the NWS validation test of AFOS in August-September 1981, which was limited to selected products and operations, does not justify full implementation of AFOS on a nationwide basis. We continue to have serious reservations in terms of cost effectiveness and efficiency if AFOS were implemented nationwide in over 200 weather stations. Where appropriate, we have made changes in the final report to reflect changed conditions, improvements, and our modified positions. Further, we point out that AFOS' basic design problems still exist and that NWS has not initiated appropriate actions to resolve them.

### 1. AGENCY RESPONSE

"No major problems in AFOS software, hardware, or telecommunications remain that affect its essential functional capabilities."

OUR EVALUATION

We acknowledge improvement in AFOS' performance. It is operating and carrying out limited functions.

However, deficiencies we have identified in those components are inherent in their basic designs. For example, the software component, which includes three major segments--the operating system, the applications software, and the telecommunications software--has severe limitations. In particular, the software segments are so tightly integrated in the computer's memory that major software malfunctions can be expected to occur. That is, the organizational structure of the software does not consist of independent modules that would permit changes to one module without affecting other modules. As the workload resulting from a fully implemented system significantly increases, the potential for software malfunctions likewise increases. The inappropriate structure of integrated software makes the entire software vulnerable. In particular, as one software segment fails, the remaining software segments will most likely fail. For example, the deadlock problem with the software component persits. When the computer attempts to process two or more tasks which compete with the same resource, a system malfunction occurs and the system is incapable of processing other tasks.

Also, AFOS as currently designed is not capable of interfacing with or incorporating other systems under development. For example, AFOS lacks the capability to either transmit radar and satellite imagery data to field offices or receive or process information from remote area meteorological observation stations. Consequently, AFOS meets limited system requirements, but it cannot meet all the major needs specified in its original requirements.

2. AGENCY RESPONSE

> "AFOS is sufficiently stable and reliable to use as the primary system; the existing AFOS system is now serving as the primary system in two of the four contiguous NWS regions; and operational adequacy will be demonstrated during August and September 1981."

OUR EVALUATION

Through recent onsite observations and based on preliminary test results from the August-September 1981 test, we acknowledge an improvement in reliability. We note that NWS has (1) removed a number of system features to reduce complexity and minimize system failures and (2) declared a moratorium on changes to the software to help stabilize the entire system.

However, AFOS does not qualify as a primary system until it actually replaces the current communications system and performs

its essential functions. To be the primary system, AFOS should operate as such for an acceptable period of time in parallel with the current system. But it plans to operate AFOS in parallel for nearly 3 more years, rather than several months. Not only is this lengthy parallel operation inconsistent with acceptable management practices, but it has not been justified on a cost-benefit basis. NWS has yet to demonstrate that AFOS can meet prescribed requirements and acceptable standards and practices in such areas as flexibility, expandability, reliability, backup capability, maintainability, and operability.

3. AGENCY RESPONSE

"The most important backup capabilities designed into AFOS have been implemented, and the pre-AFOS communications arrangements will be retained as an added backup through FY 1984."

OUR EVALUATION

Although certain backup capabilities have been tested and the procedures appear to work satisfactorily, limitations and deficiencies continue to exist. For example, when the System Monitoring and Coordination Center's computer/telecommunications system fails, its backup procedures do not assure continuous operation with minimum interruptions. Continuous operations are highly dependent on the SMCC, the heart of the AFOS telecommunications network. All weather service information must be transmitted through the SMCC from the large computer system at the National Meteorological Center to the 200 field offices and from field offices to the NMC. Also, information flowing to and from the NMC from all sources must pass through the SMCC, including information exchanged with other weather services (FAA, Air Force, and Navy).

Further, the operation of computer systems dispersed nationwide is completely dependent upon the nationwide telecommunications network for all essential functions. If any of the WSFO computer systems fail to function for 10 minutes or longer, an operator must manually pull a bypass switch to cut the failed system out of the telecommunications loop. Failure to do so will result in lost data and operational problems in the adjoining stations on the network.

In addition, particular limitations and deficiencies with the backup procedures exist in WSFOs where the system has two minicomputers. When one computer fails, the second computer must continue to perform its normal telecommunications function as well as handle the other computer's load. In this instance, the second computer operating in a degraded mode results in slower processing of fewer functions. This condition is compounded by the computer's lack of core memory to handle the increased workload, thus resulting in a high-risk situation.

4. AGENCY RESPONSE

"Improvements in AFOS have been incorporated successfully during the last year, and NWS believes that some investment in selective improvements (not fundamental redesign and development), retaining the existing hardware and most of the software, will further improve system performance and facilitate future software maintenance and enhancement."

OUR EVALUATION

Based on our observation of NWS' August-September 1981 AFOS validation test, we agree that NWS has made improvements in AFOS. However, the improvements, in part, resulted from removing existing capabilities to relieve a shortage of core memory to improve reliability. The improvements have also resulted from the extensive use of personnel and management attention to increase system discipline and apply standard operating procedures. Nonetheless, we are concerned that this level of support cannot be sustained over the next 8 to 9 years.

NWS stated that the current plan is to freeze the system "as is" and hold all changes to a minimum. AFOS technical and management personnel have determined, and we agree, that AFOS' problems stem from fundamental design flaws which can be resolved only by a major redevelopment. In short, the potential for substantial improvement in AFOS has been precluded by NWS' approaches to solving immediate problems. By stating that it plans to freeze the system, NWS clearly states that the AFOS design will not be improved.

5. AGENCY RESPONSE

"The cost of operating and maintaining AFOS is close to the projections made in 1976 when adjusted for the effects of inflation on salaries and spare parts."

OUR EVALUATION

Since we did not review this aspect, we have no basis to accept or reject NWS' statement. Due to the lack of cost data available from the NWS accounting system, we did not attempt to determine the cost to maintain and operate the system. In essence, our review focused on the cost to develop AFOS. NWS itself provided the cost figure of $13 million per year for operations and maintenance that we have used. The only adjustment we made was to allocate overhead to the $13 million as required by NOAA and NWS accounting procedures.

6. AGENCY RESPONSE

"The existing AFOS system meets all significant original requirements except for early withdrawal

of teletypewriter and facsimile capabilities, retained as backup, and substantially exceeds original expectations in some areas such as forecaster assistance."

OUR EVALUATION

NWS stated that AFOS meets or exceeds the original requirements as specified in the June 1976 Program Development Plan. NWS' reference to the 1976 document as the original requirement is misleading. The 1976 document is a general overview description of AFOS. This document was prepared 2 years after the original specifications and does not meet the standards for a program specifications or requirements document. In 1974 NWS developed a detailed set of program requirements that became the basic design document for AFOS. We still contend that AFOS does not meet NWS specifications as cited in its original 1974 system requirements document. In fact, following its 1981 technical assessment, NWS itself concluded that AFOS is unable to meet the original program specifications.

7. AGENCY RESPONSE

"The initial AFOS system was never intended or designed to meet all future requirements, and particularly not those cited by GAO."

OUR EVALUATION

NWS' original program specifications document of 1974 and all subsequent specifications documents have specifically stated that the use of radar and satellite data, as well as the new remote area meteorological observing systems under development, would be part of AFOS. Further, these requirements documents place a top priority on flexibility and the ability of AFOS to handle new systems and program changes. In addition, a top priority was assigned to the requirement that the meteorologists, inexperienced in ADP and telecommunications, would be able to operate and use AFOS without intensive training. As NWS itself concluded in its March 1981 technical assessment, AFOS is unable to meet these requirements.

AFOS is also unable to meet NWS' original specifications on frequency of software breakdowns, time to repair hardware and correct software, backup levels of protection, and a number of computerized routines to support the forecasters. Our position is also supported by NWS' assessment that AFOS is not capable of handling radar and satellite imagery data and other requirements in its original specifications. Further support for our position is illustrated by NWS' decision to begin developing a new system to meet mission needs and to overcome AFOS' limitations and deficiencies. A new system to replace AFOS by 1989 was one item which did not appear in NWS' requirements documents.

8. AGENCY RESPONSE

"AFOS is extremely valuable to NWS operations; it significantly speeds up warnings and forecasts as planned, saves large numbers of staff-hours annually through automation of routine tasks, liberates time and resources for service improvements, and establishes a mode of operation amenable to future improvements."

OUR EVALUATION

In spite of its limitations, AFOS does, we agree, speed up warnings and forecasts. We disagree with NWS that AFOS has resulted in personnel savings. As we noted in the report, NWS has added 119 positions to develop and operate AFOS; it has no basis to attribute personnel reductions to AFOS. NWS continues to discount the significant personnel costs for training, managing a telecommunication system, and providing the management and technical support required by a complex ADP system. Most of these services were previously supplied by FAA at no cost to NWS.

Until NWS begins collecting and accounting for personnel costs as required by NOAA and NWS accounting procedures, NWS will continue to underestimate AFOS personnel costs. A key reason for establishing these accounting procedures was to provide management with the true cost of ADP systems development and operations. Without this information management has no basis on which to determine total personnel costs to its organization by specific projects. NWS continues to neglect the collection and analysis of cost information for AFOS.

AGENCY RESPONSE

9. "GAO's estimate that $116 million could be saved by not operating AFOS for 8 years does not consider important costs of trying to turn back to operations without AFOS, and totally ignores the major capabilities and efficiencies that would be lost."

OUR EVALUATION

As disclosed in our report, the cost savings originally identified by NWS as AFOS' benefits will not be realized. During our review of AFOS we repeatedly requested that NWS prepare a cost-benefit analysis. Yet, NWS repeatedly stated that it was unnecessary at this point in time and that it had no plans to conduct such an analysis. Without such benefit and cost information, neither NWS nor any cognizant organization, including GAO, NOAA, or congressional committees, is in a position to compare the benefits against costs.

10. AGENCY RESPONSE

"Reverting to pre-AFOS systems involves much more than retaining connection to FAA's teletypewriter circuits, including refurbishing or replacing aging equipment of various types, substantially increasing field personnel, and making other potentially expensive adjustments."

OUR EVALUATION

The current communications system, without the AFOS system, has been operating for many years and continues to meet NWS' basic requirements in all six regions.

Further, NWS stated that it plans to retain the current system until 1984. Although additional funds would be required to maintain or replace the current communications system, continuing to operate AFOS would be considerably more expensive. For example, in its March 1981 technical assessment, NWS identified $12 to $15 million as the amount needed to upgrade AFOS. This does not include expenditures to resolve basic AFOS design deficiencies and constraints.

11. AGENCY RESPONSE

"Even current services could not be maintained using pre-AFOS systems without a major investment and upheaval in NWS, if at all. The pre-AFOS systems do not meet even 1974 NWS requirements; that is why the AFOS program was initiated to provide many capabilities not included at all in the previous systems."

OUR EVALUATION

Current services can be maintained without AFOS as evidenced by the fact that NWS is providing all current services using its current communications system, not AFOS. In addition, NWS stated that it plans to retain the current communications system as a backup to AFOS. This backup plan, therefore, supports our position that as AFOS fails to perform and does not provide needed services, the current communications system can provide these services.

It is also important to note that with the exception of limited data processing capability for local programing, AFOS does not have any major capabilities not contained in the current system. AFOS basically performs the same major functions as the current system. The additional capabilities planned for AFOS, such as handling radar, satellite, and remote observations, have been deleted from the system. NWS expects to include these requirements in the new system it plans to develop.

12. AGENCY RESPONSE

"Totally different kinds of personnel are involved in operating AFOS and in developing a new system; NWS can accomplish both concurrently."

OUR EVALUATION

NWS does not adequately account for the agency's experience with AFOS during the very lengthy and costly development phase which began in 1974 and is continuing. Field operating personnel invested a significant amount of time in developing, testing, and operating AFOS. This time expenditure is likely to be repeated when NWS is again involved in a new system development effort and concurrently maintaining AFOS to meet its needs.

Also, NWS does not adequately address the agency's severe lack of management and technical personnel who are experienced in ADP development. Developing a new system, in addition to supporting AFOS and maintaining the current system, will place an excessive burden on both management and technical personnel. Further, by not adequately assessing the total personnel needs based on a system to properly account for personnel costs, NWS will continue to pass over the very real and heavy investment of its personnel in AFOS development and operations.

13. AGENCY RESPONSE

"The cost of a new system meeting all present and future requirements recommended by GAO is unknown, and GAO's estimate of $125 to $150 million is not based on any substantive analysis or knowledge of the requirements; and

"the assumption that more than $100 million, now planned for expenditure in small pieces over eight years, can be gathered up for a procurement is at best doubtful."

OUR EVALUATION

NWS objected to our estimate that the development cost of a new system would be $125 to $150 million. We believe that this estimate is reasonable in light of AFOS development, which when completed will have cost about $150 million. With the effects of inflation on personnel costs for software development (the major cost of an ADP system), it is very unlikely that a new system would cost less than $125 to $150 million.

NWS also disagreed with our position that over $100 million scheduled to be spent in small pieces over 8 years could be accumulated for the procurement of a new system. We agree with NWS and would like to point out that we neither stated nor assumed

this was the case. It is our position that a new system development project should be approved and funded by the Congress and not internally reprogramed from operations and maintenance funds.

14. AGENCY RESPONSE

"The development of large, complex systems that break frontiers should be expected to encounter some problems; NOAA's experience shows that proceeding in a series of ambitious but prudent steps results in fewer problems than making a single giant leap to a new system incorporating even more novel features than AFOS, as proposed by GAO."

OUR EVALUATION

We acknowledge the new frontiers penetrated by NWS in initiating the AFOS project. We also acknowledge NWS' position that it intends to replace AFOS with a new system. This new system is designed to meet requirements identified by NWS in 1974 and to incorporate additional requirements to meet mission needs. Our report does not recommend specific capabilities for AFOS, but it identifies the areas in which AFOS lacks capabilities prescribed for it in the 1974 requirements. Further, our reservations are directed toward the cost and advisability of operating AFOS.

15. AGENCY RESPONSE

"The schedule to complete AFOS slipped 2 years, not 5 years."

OUR EVALUATION

AFOS will be fully operational only when the current system is removed in 1984 and all stations are using AFOS as the primary system. In developing AFOS and in its internal plans prepared prior to responding to our report, the development phase was to end in 1979 and the removal date of the current system was the termination date of the development phase. NWS' revised position is that the development phase will end in 1982 when it expects all scheduled offices to be using AFOS, even though the current system will remain in operation until 1984. Further, in development projects in the private sector and in Government, the date the current system is removed normally indicates the end of a development phase. By this measure AFOS is 5 years behind schedule.

16. AGENCY RESPONSE

"NWS used management practices appropriate to the stage of development and the organizational realities of NWS."

OUR EVALUATION

As we noted in our report, technical assessments by independent contractors as well as by us have noted major management problems in AFOS development. NWS has not followed standard Government guidance and acceptable management practices for system management, accounting, and software development. Such management deficiencies have significantly contributed to AFOS' delays and problems.

In March 1981, following a detailed analysis of AFOS, the project manager in his final report summarized NWS' management problems as follows:

> "The consultants we retained in recent years, as well as the GAO team currently reviewing the AFOS program, have stressed that other organizations successfully undertaking automation programs of the scope and complexity of AFOS were forced to make significant organizational and management changes. These were necessary to accommodate this level of automation and to institute much higher levels of classical systems engineering and management disciplines than the NWS has invoked to date. We have been repeatedly warned that we risk continued problems and failure unless we exercise a higher degree of discipline in the establishment of requirements, development, operation, change management, documentation, support and program management than is exercised in the customary practices of the NWS.
>
> "Our experience during the past year seems to confirm these views. Many of our problems can be traced to failures of management and systems discipline. These have lead to unrealistic plans, schedules and expectations. Priorities in allocation of staff and resources have been obscure, confusing and inconsistent through the organization. The flow of up-to-date, authoritative, honest information has been spotty and slow, and the exercise of management direction often has been weak and fuzzy. Collegial decision-making has promoted participation at the expense of focus, clarity and decisiveness."

We concur with this assessment. It should also be noted that NWS attempted to develop one of the largest distributed data base systems ever designed, in-house, without trained ADP personnel, without increasing staffing levels, and without modifying its organizational structure. Given these constraints, management and technical problems are not surprising. ADP development projects require strong central management and heavy emphasis on systems discipline.

APPENDIX I

We recognize that NWS must retain full management responsibility for ADP projects. We believe, however, that by using contractors to perform technical tasks and concentrating NWS personnel on project management, the development of a new system could be improved. This would permit ADP personnel to complete technical work they are trained for, and NWS could concentrate on the management and meteorological issues which it is best able to address.

APPENDIX II

**UNITED STATES DEPARTMENT OF COMMERCE**
**Office of Inspector General**
Washington, D.C. 20230

AUG 31 1981

Mr. Henry Eschwege
Director, Community and Economic
Development Division
U. S. General Accounting Office
Washington, D. C. 20548

Dear Mr. Eschwege:

This is in reply to your letter of June 29, 1981, requesting comments on the draft report entitled "The National Weather Service Should Abandon the Automation of Field Operations and Services System."

We have reviewed the enclosed comments of the Deputy Administrator, National Oceanic and Atmospheric Administration for the Department of Commerce and believe they are responsive to the matters discussed in the report.

Sincerely,

for Frederic A. Heim, Jr.
Assistant Inspector General
for Auditing

Enclosure

APPENDIX II

Comments of

National Oceanic and Atmospheric Administration *

Department of Commerce

on

GAO Draft of a Proposed Report

on

"The National Weather Service Should Abandon
the Automation of Field Operations and Services Systems"

Dated

July 24, 1981

* With OMB changes of August 26, 1981

APPENDIX II

TABLE OF CONTENTS

APPENDIX II

CHAPTER 5 - AFOS TELECOMMUNICATIONS

AFOS Telecommunications Design
Reliability
Telecommunications Technology
Conclusions
Recommendations

CHAPTER 6 - AFOS HARDWARE

Current Status
AFOS Logistics System
AFOS Operating System
Hardware Capacity
Hardware Replacement
Conclusions
Recommendations

CHAPTER 7 - FUTURE OF AFOS

## OVERVIEW

### AFOS Status Update

The technical problems that delayed operational implementation of the Automation of Field Operations and Services (AFOS) program now have been isolated and resolved. The performance of AFOS hardware, software, and telecommunications meets all functional and technical requirements established by the National Weather Service (NWS) as essential for proceeding with the formal operational demonstration. Already two of the four contiguous NWS regions are relying on AFOS for nearly all planned service operations. The system has been installed in all of the more than 200 field offices as planned, the communications links have been established, and AFOS is supporting some critical operational needs at all of these stations. The NWS regions using AFOS as the primary system report that it significantly speeds the preparation and dissemination of severe weather and flash flood warnings, one of the major original goals of the program. Equally important, AFOS provides staff relief to NWS field offices by automating numerous time consuming manual tasks and simplifying many others.

A formal operational demonstration has been designed to verify that full weather service operations conducted using AFOS as the primary weather information system meet rigorous, quantitative standards of reliability and timeliness. The hardware, software, network maintenance and logistics systems, and other support elements already are in their final configuration for the demonstration; the field personnel of two entire NWS regions are fully trained and proficient; and the demonstration will be completed by the end of September 1981 as scheduled. Assuming successful completion of this operational demonstration plus prior completion of an extensive technical validation of the AFOS system covering the last 18 months and a comprehensive program of field training and verification of operational and support procedures, NWS plans to proceed with national implementation of the system. The NWS plans that its regions will be formally commissioned, one-by-one in a phased process, resulting in all four regions operational by the end of FY 1982.

### Basic Issues

Two factors stand out in the basic conflict between the preceding summary of the status and plans for AFOS implementation and the major conclusions and recommendations of the GAO draft report. First, there has been positive progress in the development, testing, and initial field use of the AFOS system since the GAO completed its visitation and data collection activities several months ago. Second, NOAA and GAO have significantly different perspectives on the nature of weather service operations and the requirements, relative importance, and value of various technical and service capabilities associated with AFOS.

In essence, there are two fundamental issues that separate NOAA and GAO.

1. NOAA contends that the AFOS system will meet the agency's requirements for support of weather service operations in essential accordance with its design and original program goals, and plans to implement the system operationally beginning this fall with phased extension across the country by the end of FY 1982. In contrast, GAO concluded that the system cannot meet its original requirements and must be completely redeveloped.

2. NOAA believes that AFOS should serve as the primary information system supporting NWS field operations for the next 7-9 years, and plans to develop a new system incorporating major added capabilities for implementation near the end of the decade. In contrast, GAO recommends that NWS abandon further efforts to develop and use the existing AFOS system and concentrate its resources on the development of a new system to replace AFOS. In the interim period, GAO proposes that NWS should revert to total reliance on the systems and procedures in use prior to the introduction of AFOS.

Performance vs. Requirements

The first issue outlined above involves two essential elements: a) the actual performance capabilities of the system, and b) the requirements of the agency. The performance of the system is observable, and in principle, subject to agreement as "fact." Unfortunately, GAO observed the system at an earlier stage of development when a number of technical problems had not yet been resolved. In the last few months there has been marked improvement and stablization in system performance. In fact, two of the four contiguous NWS regions currently are using AFOS as the primary weather information system supporting normal, day-to-day service operations. Nearly all of the approximately 200 NWS offices equipped with AFOS are depending on the system for some important functions such as preparation of forecast and warning messages. The test and demonstration activities of the next 2 months will provide quantitative observations of the performance of the system under real, operational conditions, 24 hours per day, over an extended period.

The question of requirements is more subtle. It could reduce down into a legalistic argument, in a historical context, with reference to various documents associated with the program and system development process. This is a natural route for auditing. Inevitably, questions of interpretation, intent, changes, and the adequacy of documentation arise from this approach. The NWS believes that the AFOS system does in fact meet the requirements set forth when the program was initiated in 1974. A more fundamental argument, however, is that normally the

user agency is in the best position to judge whether a system meets its requirements or not, whether they have changed or not, and whether they are adequately documented or not. In subsequent sections, specific capabilities already in use and their relevance to weather service operations are summarized.

We recognize that system performance and associated requirements comprise much more than functional capabilities. System reliability, maintainability, backup capability, flexibility, complexity of operations, cost of operations, and similar factors are important. After careful review and evaluation NWS has judged the AFOS system design and performance satisfactory in all of these aspects. Justifications supporting this assessment are presented in subsequent sections. NWS judgments of the technical performance and operational suitability of the system are based on actual current experience with the system. In contrast, GAO's conclusions are based on observations only during earlier development stages when problems are normal and expected. GAO's major conclusions rest heavily on extrapolations based on general principles and experience with other ADP systems.

This is not to deny that there have been significant problems with the system in the past, nor to suggest that there are no system characteristics that could be improved. Nevertheless, the existing AFOS system as designed, developed, installed, and used in the field, meets essential requirements of service operations. One notable deviation from our original plan is the decision to retain teletypewriter and facsimile capabilities at AFOS-equipped offices for the first 2-3 years of operation.

The rationale for retaining these systems is threefold. First, they provide a proven backup in case of unexpected failures in the AFOS system. This backup approach was an integral part of the decision to streamline the design of the System Monitoring and Coordination Center (SMCC) near Washington, D.C., thereby limiting some built-in AFOS backup capabilities. Details are presented later, but NWS considers this backup arrangement to obviate the concerns expressed by GAO about the deferral of some previously planned backup modes within the AFOS system. Second, other weather field offices not equipped with AFOS must rely on these systems anyway until they are equipped with leased, remote terminals during the next 2-3 years. Finally, it is prudent to retain the old familiar system for an interim period as a "safety net" during the transition to an entirely new technology and mode of operation.

Value of AFOS

The second major issue identified above rests more on the different value systems in which the judgments are made. The contrasting conclusions result from different judgments not only on what is needed by NWS and when, but also on what is possible, what is practical, what is acceptable, and what is "worth it."

NOAA and GAO agree that eventually (we project possibly the end of the decade) NWS can and should develop a new system which incorporates additional capabilities that cannot be added to AFOS without major design changes. The original Program Development Plan for AFOS recognized that an additional development phase would be needed, although it was somewhat optimistic (in hindsight) in projecting the mid-1980's for this stage. Much of the research and development work needed for an advanced system is underway in NOAA, research institutions, and industry. A specific planning effort directed toward acquiring such a system has been initiated by NWS. NOAA recognizes that major and time-consuming program and budget decision processes in both the executive and legislative branches will be required before such a program could proceed beyond a modest planning effort.

However, today and every day from now until a new system is available, the Nation requires weather services. NOAA must provide these services in the most effective and efficient way available. We are convinced that AFOS provides a significantly more effective and efficient way of providing weather services than has ever been available. After coming this far with AFOS, it is even difficult to imagine how to conduct our operations without AFOS. The termination of AFOS, for whatever reason, would be a major set back to progress in weather services.

Obviously, if the AFOS system failed to function in a way that is essential for service operations, it not only shouldn't but couldn't be used as the primary operational system. We believe that we have shown that the system will demonstrably meet essential requirements. In this case, a question still remains, is it "worth it." To answer this, we must answer what are the alternatives and what are their comparative advantages and disadvantages.

The draft GAO report sketches out one rationale for such a comparison, based on the concept of "savings from not using AFOS between now and the end of the decade." It is asserted that $116M would be saved, a number surely large enough to be impressive. However, it is based mainly on multiplying GAO's estimated annual "operating cost" by a large number of years, and thus could be made even larger by deferring a new system even longer! Quite apart from disagreements on the precise amount of the cost estimates for operating AFOS, this approach is inadequate in other respects. It assumes that the only other "cost" that should be considered when providing weather services without AFOS is the current NWS cost of using the FAA teletypewriter system multiplied by the number of years considered. Even this cost factor is misleading because FAA pays the bulk of the cost for the current system and plans to discontinue it in favor of a system using AFOS-type technology during the projected time interval.

Even more serious are the implied assumptions in such a rationale, e.g., that operating with AFOS and with the FAA teletypewriter network are somehow equivalent (they aren't), or that it is even possible to continue operations with the current technology at any cost for this time period; or that the relief from manual tasks that automation provides is without value, or conversely, that NWS could maintain essential services without additional costs. Perhaps most crucially, maintaining services without AFOS would require additional personnel, and they have become even more scarce, valuable, and costly than ever during recent years.

Compounding these deficiencies in GAO's analysis is the complete neglect of the comparative quality of services using the two systems. We have demonstrated that AFOS significantly speeds the preparation and dissemination of weather warnings as compared to the current system (one of the major goals of AFOS). This is an important value of AFOS, and its loss should be an important cost in an economic analysis. Furthermore, AFOS increases the quality of analysis and forecast products in numerous ways by providing new tools to assist forecasters in analysis and interpretation of weather information. The improvements in service quality will grow with continuing use of the system and exploitation of its inherently new and powerful capabilities to process and display information.

It is clear that it is a gross and sterile oversimplification to equate not using AFOS to a cost savings of $116M -- or any numerical figure quotable solely in dollars.

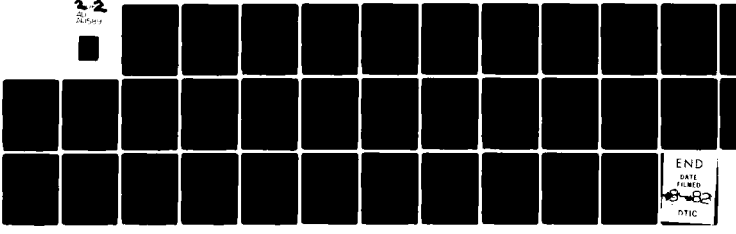
Outline of NOAA's Detailed Comments

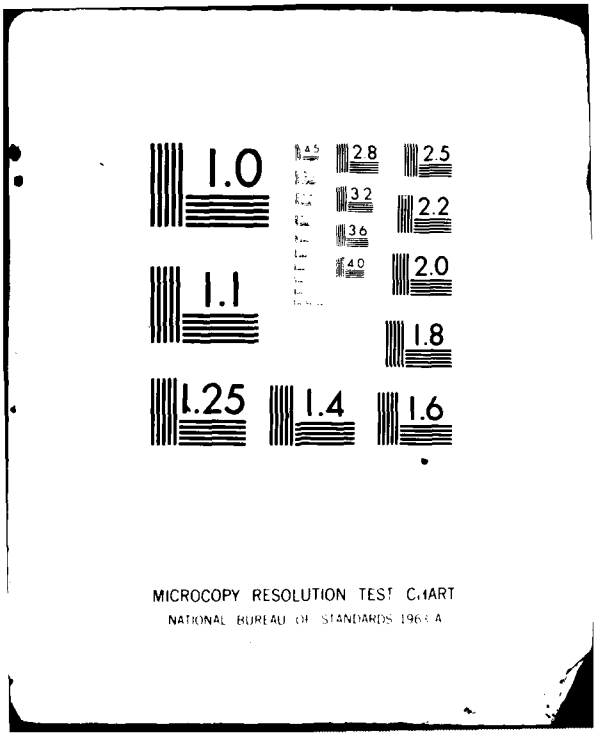
The remainder of NOAA's comments following this overview is organized in accordance with the chapters of the draft GAO report with the exception of chapter 1. GAO's chapter 1 deals mainly with background and organization of the National Weather Service without conclusions or recommendations. There are a few factual errors and NWS is working directly with GAO to correct these.

At the beginning of chapter 2, we have pulled together in one place an up-to-date summary of the current status of the AFOS system. This is especially important because GAO gathered nearly all of the information used to prepare the draft report during the period between July 1980 and March 1981. A number of the criticisms refer to situations or practices which have subsequently been altered. In particular, most of GAO's observations concerning the actual performance of the system, and judgments derived from those observations date from a major engineering system test conducted under field operating conditions during January 1981. Since that time, engineering testing has been completed, and problems that GAO staff considered intractable have been overcome. The system performance

AD-A111 589 GENERAL ACCOUNTING OFFICE WASHINGTON DC COMMUNITY AN--ETC F/G 9/2
PROBLEMS PLAGUE NATIONAL WEATHER SERVICE ADP SYSTEM.(U)
NOV 81

UNCLASSIFIED GAO/CED-82-6 NL




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

now meets all NWS primary functional and technical requirements, and we are beginning to rely on AFOS as the primary weather information system in a substantial number of NWS field offices. AFOS telecommunications, data organization and manipulation, analysis and forecast preparation, automatic dissemination network control and backup capabilities all now meet essential NWS requirements. The current levels of these capabilities are outlined at the beginning of chapter 2.

Chapter 2 also includes a section on costs and schedules which should correct several misconceptions that seem to exist on these topics. A confusion between early budget estimates referring to obligational authority (exclusive of overhead and routine cross-utilization of existing support functions) and accountable costs is clarified. This permits a more reasonable comparison of actual versus projected costs. Similarly, the actual evolution of the AFOS schedule, some of it in reponse to changes in budget profile, is presented. The rationale that leads to GAO's surprising conclusion that AFOS is 5 years behind schedule is examined, and NOAA concludes that 2 years is a more reasonable estimate. Finally, chapter 2 of these comments addresses the value that NOAA already derives from AFOS and expects to achieve from future use of AFOS, and compares these to early expectations when the program was launched.

Chapter 3 addresses the management of the AFOS program. A summary of the current management structure, policies, and practices is provided along with the rationale for them. Again, some significant adjustments have been made which may account for part of the large disagreement on management between NOAA and GAO, but we suspect the explanation rests more directly on the fact that NWS cannot limit its management considerations so narrowly to ADP issues as GAO recommends. We conclude that the successful development of AFOS to its present level, ready for final operational demonstration, is a better measure of program management than the alleged departure from general principles of ADP management.

Chapter 4 summarizes the nature and status of AFOS software. The facts presented refute the GAO claims that AFOS software is inadequate and explains how sound technical and management techniques were used to correct software problems encountered earlier in the program. NOAA considers that successful development of reliable AFOS software that accomplishes such a wide array of concurrent functions is a significant achievement. The great complexity and tight integration of the software is acknowledged by NWS, along with the consequence that further changes and improvements are difficult and time consuming. However, these limitations do not affect the ability of the system to support weather service operations as planned. Furthermore, after the initial system has been commissioned, NWS plans to relieve these limitations and do so without additional resources beyond the level requested for FY 1982.

Chapter 5 summarizes the nature and status of AFOS telecommunications. Of all the technical issues related to AFOS, this one has provoked comment and concerns of the most diverse character and origin. Perhaps this occurs because the superficial concepts of network structure can be understood by anyone, and most persons agree that network concepts exist that appear superior in one way or another to the loop design selected for AFOS. NOAA bases its program decision on the fact that the selected design successfully meets all operational requirements for the system and does so with reasonable resources. NOAA will continue to review alternative possibilities and be alert for opportunities to improve performance or achieve economies, but there is no known basis for rejecting the existing successful design. It is anticipated that major extensions of weather information systems currently under initial study for the end of the decade will likely require a more advanced design.

Chapter 6 summarizes the nature and status of AFOS hardware. The facts clearly contradict the assessment of GAO. In addition to the timing problem of GAO's observations mentioned before, there are other possible explanations for this discrepancy. First, in the complex AFOS system, it is never obvious to an observer whether a functional failure at a site is due to a software or a hardware problem or even to a problem within the telephone companies' line and switching systems. After completion of validation testing, NWS has determined that nearly all of the "failures" observed during the period of GAO's visitation were caused by software "bugs" which were readily corrected. Second, the GAO report points out that the equipment used in AFOS does not take advantage of the most recent advances in electronic design. This deficiency exists in every major system procured by the government and would exist in the new system that GAO proposes be developed to replace AFOS, because advances in electronics occur rapidly while system procurement, integration, testing and introduction to service take several years. Again, the proper test is performance, and the AFOS hardware meets all specifications for reliability and maintainability. The criticism that the cost of operations and repair will be excessive is unsubstantiated and counter to NWS experience with AFOS to date and with analogous systems.

Chapter 7 examines the validity of the composite assessment of AFOS. The basic tenets that are used to support GAO's conclusion that AFOS should be abandoned are considered and found to be invalid in the other chapters as noted above. The GAO report concludes that the AFOS system cannot work. In fact, the AFOS system already does work as shown not only by engineering tests but by actual reliance on the system by many NWS offices to provide primary operational support (even though the system has not yet been formally commissioned). Any remaining doubts about the adequacy of the system to support operations should be settled by the objective, formal operational demonstration scheduled to be completed by the end of September 1981.

The GAO also questions whether the introduction of AFOS is justified. This is not a new question and was considered by NOAA, the Executive Branch, and Congress before the program was authorized. The current system as developed achieves the objectives anticipated except for the withdrawal of existing teletypewriter and facsimile systems which would save an estimated $2.6M annually. NWS plans to achieve the latter savings by the end of FY 1984. Nearly all of the investment of resources (7 years of effort and nearly $100M according to GAO) already has been made to achieve these objectives.

The only argument remaining might be that it costs too much to operate the system (about $13M annually by NOAA's estimate or $15M according to GAO including unrecoverable overhead costs). GAO compares this only to their estimate of $3.5M annually for NOAA to connect to FAA's teletypewriter circuits. Significant additional costs would be required under this option in order to refurbish and replace equipment that would be essential with the "old system" but is being phased out with AFOS; to add approximately 150 technicians to operate labor intensive services, such as NOAA Weather Wire; to assume the entire cost of operating national teletypewriter circuits following FAA's planned termination of them in the mid-1980's and other costs associated with termination of the AFOS personnel, facilities, and equipment. These direct costs would be magnified by the loss in productivity of NWS personnel, degradation in the quality of service and lost opportunity to make planned improvements in services. The NWS allocates about $100M annually just to pay the people who provide weather services, and a comparable amount to provide support, systems development, etc. NOAA believes that an investment in AFOS of this proportion, one that promises to modernize and improve the entire mode of operations of NWS, and one which provides the only known path to improved services without increasing personnel levels, is worth it.

## CHAPTER 2

## CURRENT STATUS AND COST OF AFOS

### CURRENT STATUS OF AFOS

There have been improvements made in the performance, capability, and stability of the AFOS software, hardware, and telecommunications in the last year and a half. The system's capability to assist the forecaster meets or, in some cases, exceeds original plans. This has been achieved through an innovative and systematic test and design validation program and a phased introduction of AFOS into actual field operations.

Contrary to the performance observed by the GAO team approximately 6 months ago, AFOS is being used as the primary tool by forecasters in the preparation and delivery of weather services by two of the four contiguous NWS regions. NWS anticipates by the end of FY 1982 to have commissioned AFOS operations at all planned sites in all four contiguous regions.

AFOS brings to Weather Service operations technological capabilities heretofore unavailable to weather forecasters. In addition to providing an advanced telecommunications capability far exceeding the capability of current teletypewriter circuits in use at field sites, AFOS provides the capabilities for sophisticated local data organization and manipulation, powerful new analytical capabilities, as well as significantly enhanced forecast preparation features. AFOS brings to NWS operations the capabilities of automated dissemination of warnings and services. These unique capabilities provided by AFOS directly improve the productivity and effectiveness of NWS personnel which results in improved timeliness and quality of NWS warnings and forecast services.

#### AFOS Telecommunications

The AFOS communications system is proving to be significantly faster than the existing teletypewriter and facsimile systems. It is being used today to distribute on a routine, 24-hour-a-day, 7-day-a-week basis, the products and data necessary for operational use. This information is automatically transmitted with built in error-detection and retransmission capabilities. The products used in forecasting arrive significantly sooner and provide additional lead time for field forecasters to interpret weather situations and formulate their state and local forecast products. The Regional Distribution Circuits are carrying synchronous communications with fully satisfactory performance and reliability. Both alphanumeric and graphic products are available on time or earlier. In the event of computer

failure or telephone line outage, both automatic and manual backup procedures are in place and proven under actual field use.

Data Organization and Manipulation

The AFOS system incorporates the feature of a distributed data base resident at each site. This feature coupled with the computer controlled and managed telecommunication system of AFOS accomplishes the automatic reception, storage, and updating of the station's data base. Station staff are being relieved of the requirement to handle the large, continuous stream of products on paper rolls used by the teletypewriter and facsimile systems. AFOS automatically alerts forecasters when any product of special interest, such as warnings and watches for severe weather and flood events, enter the local office. Thus, the automated communication capability provided by AFOS is saving valuable time of field staff, preventing oversights and errors, and permitting increased emphasis on service and productivity. The localized data base is tailored to each station's need and can be supplemented by the high speed request/reply feature of AFOS making the master data base of over 30,000 products instantly available to the forecaster.

Analysis and Forecast Preparation

AFOS provides on-site processing capability for the first time to forecast and warning offices. A significant portion of the system's computing power is available for manipulation and formulation of data, analyses and products -- a capability that the Weather Service has never had before. Stations are now using AFOS to analyze and compute local river levels, analyze detailed moisture and wind conditions for severe weather forecasting, plot surface aviation observations, plot and analyze local and regional temperature fields, plot and analyze data for fire weather advisories, analyze upper air soundings, verify terminal and zone forecasts, compute snow pack melt, and many more local applications. The enhanced preformat and text composition and editing features of AFOS, when compared to a teletypewriter keyboard, are providing station forecasters the opportunity to directly improve the quality and timeliness of their products and services. In addition, the data processing capability frees station personnel of virtually all routine manual plotting and analysis, resulting in additional efficiencies.

Automatic Dissemination

AFOS automatically drives various external circuits, notably the NOAA Weather Wire Service (NWWS). The NWS devotes a major effort to dissemination of its products and services, and NWWS is an essential means of doing so, particularly for issuing watches and warnings of hazardous weather. This has been a labor-intensive program -- tearing teletypewriter tapes, preparing

messages for the nearly continuous NWWS transmissions, generating paper tapes to drive teletypewriter machines, and manually feeding the tapes into reader/transmitters. AFOS automatically searches its data base for those products scheduled for routine NWWS transmission, properly formats this information, addresses the messages, and automatically transmits the products at scheduled times over the weather wire with automatic priority for watches and warnings. AFOS now performs these functions automatically and eliminates others completely.

System Monitoring and Coordinating Center (SMCC)

The SMCC is designed to interface with the National Meteorological Center (NMC) computer, maintain the master data base of all weather service products transmitted over AFOS, and drive and service Regional Distribution Circuits (RDC's).

Because of its key role in the operations of AFOS, the SMCC has a special system design which incorporates the same computers used at field sites. This permits the shared use of the AFOS logistics systems. SMCC's design is modular with principal functions assigned to separate computer systems. Each major computer system is fully backed up with a second system and automatic switching equipment to convert quickly from one system to its backup.

SMCC has been receiving NMC data and maintaining the AFOS master data base for several years. Having successfully completed the validation tests at SMCC ahead of schedule, the SMCC is now fully configured and driving each RDC as it was designed to do, and is providing network monitoring and site assistance services. The operation of all computers is stable and reliable. Two network services, master console dial-in (a third level backup) and site data base replenish, were deleted after the comprehensive program review earlier this year, both having been judged as not essential for the national implementation of AFOS. Their removal also reduced system complexity somewhat and contributes to improved stability.

AFOS Back-up Capability

AFOS has sophisticated, multiple levels of operational/service, systems, and telecommunication back-up modes. Telecommunication backup is discussed in detail in Chapter 5. Since regional precommissioning efforts moved into full swing, the development of detailed operational/service back-up procedures began, and they have been tested in actual emergency situations.

The initial AFOS design for system backup is as follows: a WSFO's equipment complement includes dual computers and a Master Console. (Master Consoles are similar to "smart terminals" on

the market that contain microprocessors and telephone modem equipment in addition to the keyboard and CRT display.) In normal operation, one computer is assigned primary communication responsibility and the other is assigned processing responsibility. Each computer can perform either principal function, and with somewhat reduced capability, can perform both functions simultaneously. If both computers fail at once (this is projected to occur once in 2.5 years), the Master Console can dial into a remote site and function like another console at the remote location.

The operation protocol at a site is as follows: (1) Normal mode -- dual computer operation, (2) back-up mode -- single computer operation (either computer), and (3) third level backup -- Master Console dial-in to a remote site.

A WSO has a single computer and Master Console. Its operations protocol in event of a computer failure is Master Console dial-in to a remote site.

All modes of backup have been tested and are in use today.

AFOS permits NWS sites for the first time to quickly and effectively initiate operation/service backup wherein service responsibilities at a failed site (due to catastrophic types of failures like lightning hits, tornadoes, telecommunication and power outages, etc.) are assigned to another (one or more) site. For example, each WSFO has primary responsibility to drive a number of NWWS circuits in its state. Using AFOS, servicing NWWS circuits is an automated procedure -- the directory of products and timetable for delivery of each are contained in the AFOS computers which automatically issue the prescribed products in accordance with those schedules. In order for the backup WSO to assume responsibility to drive that state's NWWS circuits, WSO personnel need only issue a few commands to its AFOS computer and "hit a button" -- the computer which has a duplicate of the NWWS transmission schedule then takes over automatically. Other service operations are similarly transferable to back-up stations.

Summary of Current Status

In summary, there has been remarkable progress since the GAO field visitations to the NWS. All AFOS hardware and communications are installed with all four regional loops being driven by the SMCC. The AFOS system is now being used in operations throughout the NWS and is the primary system for preparation of weather forecasts and warnings in the Central and Western regions, the two of the four regions most advanced in operational use of the system. Performance of the system is continuing to improve daily as field personnel gain experience in its operation and the improvements learned from the recently concluded test and evaluation efforts are applied. Its capability to assist the forecaster meets or exceeds, in some areas, original plans.

NWS is prepared to move forward to the Operational Demonstration of AFOS. Assuming a successful outcome, final commissioning of the system for field operations would occur. The detailed test plan has been prepared for the Operational Demonstration and the arrangements for gathering and analyzing the demonstration data are in place.

AFOS SCHEDULE AND COSTS

NOAA perceives the AFOS program to be 2 years behind schedule, not 5 years as GAO contends. The 5-year differential cited by GAO is derived using the estimated operational date of August 1979 in the FY 1974 AFOS Program Development Plan (PDP) and the currently estimated date for the completion of the removal of existing teletypewriter communications by the end of FY 1984.

The 1976 AFOS PDP reflects the schedule for implementation of AFOS based on the approved funding level; the schedule in the previous 1974 PDP noted by GAO was based on proposed level of funding. According to the 1976 PDP, AFOS would be operational at all stations during the first quarter of FY 1981. Under the present schedule, AFOS will be implemented as the primary mode of operation by the end of FY 1982, approximately 2 years later than planned in the 1976 PDP.

NOAA considers AFOS to be operational at the time it is the primary mode of operation at all equipped stations (end of FY 1982) and not the protracted time used by GAO -- the date by which the standby teletypewriter and facsimile circuits are removed (end of FY 1984).

The PDP for AFOS was based on three sources of support:

1. New budget authority, as represented in the PDP that supported the budget request.

2. Development funds which existed in the NWS base budget, to support fully dedicated personnel.

3. Use of existing personnel whose functional responsibilities related to similar functional requirements within the AFOS program; for example, training, facilities, procurement, and operations personnel at NWS Headquarters and at the regions, which is the standard practice in NOAA.

GAO uses $77.6M as a base reference. This total is only the amount which appears under new budget authority (1. above) and does not include all the funding submitted to and approved by the Congress under the AFOS sub-activity for the years FY 76 through FY 80. During those years NOAA also included $5.9M reprogrammed base R&D funds to be used for AFOS development (2. above).

NWS estimates that the use of existing personnel whose functional responsibilities related to AFOS (3. above) during the period FY 1976 through 1980 amounted to $3.5M. Therefore, within the framework that the PDP for AFOS was prepared, NWS expended a total of $87.0M through FY 1980. In addition, development personnel were assigned to AFOS programs in the last 2 years to assist in the concentrated effort to solve technical problems. The salaries of these development personnel amounted to approximately $2M which should have been included in the cost of AFOS but were not. In summary, the NWS estimates the cost of AFOS to be $89M through FY 1980. This leaves a difference of $11M between the NWS estimated costs identified above and the $100M estimate of GAO that we believe stems from the substantially different accounting procedures used by NOAA and GAO to handle overhead.

Accounting Procedures

It is important to note that the NWS, as a part of NOAA, must use NOAA's accounting systems. The NOAA system is a cost based system, was approved by GAO prior to implementation, and has been in operation for a number of years.

There is a basic conceptual difference between the NWS and the GAO team in the handling of overhead. Overhead is identified and planned within the NOAA system and is then automatically distributed among all operating projects on a direct labor dollar basis. The system has always made the appropriate distribution of overhead to AFOS based upon direct labor dollars incurred and identified to AFOS. Overhead is basically a fixed pool of distributable costs; it doesn't vary markedly from year-to-year; and it was not significantly impacted -- increased -- by the advent of AFOS. Since the distribution of this overhead is not directly controllable -- it is a function of the ratio of direct labor worked on AFOS in any given year to total direct labor worked in the NWS -- and further was not a part of the funds appropriated specifically for AFOS, NWS management did not include it in the AFOS PDP and has not included it in its identification of resources available or expended for AFOS.

In arriving at AFOS development costs, NWS AFOS financial management has been, and continues to be, focused on the management of identifiable and controllable obligations, relating these to funds specifically appropriated or reprogrammed to support the development, procurement, and installation of AFOS. This practice is consistent, and therefore comparable, with the manner in which all financial data have been displayed within the various AFOS PDP's and have been represented to our various levels of review authority and to the Congress. The GAO's insistence, at this stage of the program, of including overhead in their total cost computation and then comparing it with the financial projections of the PDP, creates an end result where the true variance

between planned and actual cost is greatly distorted. In other words, the allowance for overhead the GAO made in their estimate of costs should also be added to the resources identified in the PDP for AFOS.

It should be noted that while OMB Circular A-109 was promulgated in 1976, it was not implemented in the Department of Commerce until 1978. At that point the acquisition of the AFOS system was so nearly complete that it was not considered to be applicable.

VALUE OF AFOS

The AFOS program had two basic objectives: (1) increase the lead time of severe weather and flood warnings provided to the public; (2) enhance the quality of forecasts and services by freeing the station personnel from many of the manual routine tasks now required and by providing, for the first time, the forecaster with a local application processing capability. In contrast to the opinion of GAO, the present AFOS system performs all of these functions at least as well as originally planned.

Warnings

In a weather station, peak workloads arise for several reasons; certain times of the day when the forecasts are being updated on a scheduled basis (this schedule must adhere to the needs of users, not to the desires of the Weather Service); when the weather is changing even in modest ways; and during severe weather and flooding situations. During each of these situations, the number of repetitive operations that require manual non-professional activity increases many fold and in addition, the forecaster needs the maximum information of the weather conditions in the local area, including special analyses. The value of saving the time of field personnel is most critical during these situations and in fact, it is precisely during these times that AFOS provides maximum assistance.

The success or failure of the Weather Service in providing severe weather, especially tornadoes, and flash flood warnings, depends on the lead time that is given to the public. For tornado warnings, the average lead time has been about 3 minutes. In the pre-AFOS period, the functions which are all done manually preceding the actual dissemination of warning included:

1. Recognition that a potentially hazardous condition did or would exist.

2. Determination of the degree and extent of the danger.

3. Determination of the geographic or political subdivisions exposed.

4. Formulation of the warning.

5. Determine the routing of the message.

6. Prepare the message into paper tape form.

7. Transmission of the warning on the circuits.

8. Relay of warning at adjacent stations to other circuits when watches or warnings cross state boundaries.

With AFOS, steps 5, 6, 7, and 8 are completely automated. At the conclusion of the formulation (step 4) a single key entry enters the message to the local NWWS circuit and then computers at adjacent WSFO's automatically route the warning onto other NWWS circuits. The time required to carry out steps 3 and 4 is decreased substantially by the system's message composition capabilities, including preformat of warnings, and computer programs to assist in the determination of the specific affected counties. Steps 1 and 2 are enhanced by the automatic display of existing weather conditions and guidance products that will save valuable time for the forecaster in monitoring and watching rapidly changing mesoscale weather situations and in analyzing the potential need for weather warnings or special forecasts. This forecaster assistance plus automatic display and identification of affected areas saves additional time in getting the forecast and warning to the public. Depending on the speed with which the weather situation is developing and its extent and complexity, the automation of these functions by AFOS can result in additional warning time of from 5 to 30 minutes. These minutes can be translated into additional time for the public to protect itself and its property from potential danger.

Productivity

AFOS's contribution to increased productivity is primarily in taking over the routine mechanics of forecasting duty which were discussed in more detail earlier in the chapter (map plotting, data posting, message composition, etc.) thus freeing forecasters to devote more time to more professional tasks. The value of increased capacity for production can take different forms, e.g., analyzing the weather in finer detail, updating forecasts more frequently, responding to the public for information, or in meeting requirements for improved weather services. It is difficult to express this value in quantitative terms. However, the 1976 PDP chose to use the amount of time saved as a measure of the value. Based on our experience to date, we are confident that AFOS will provide at least 1 hour saving per forecaster day at our WSFO's and large WSO's and about one half hour per Weather Service Specialist day at the WSO's. With approximately 1,000 forecasters and 1,500 service specialists, the value of staff time saved by AFOS will be over $8M per year. When familiarity with AFOS capabilities becomes

fully ingrained in the work patterns of the staff and the teletypewriter have been removed, there will be additional savings in staff time.

The program development plan projected a net savings of 177 positions. In addition, 119 positions would be reprogrammed to support AFOS. Presently 118 positions are being used to support the AFOS program, and have been allocated to maintenance, network monitoring, control, and management functions.

The source of the projected positions, including the positions saved and those needed for AFOS support, is the automation of NWWS -- a total of 296 positions. In 1976, the AFOS PDP identified 218 NWWS positions in service, plus 78 more required for the planned expansion of the NWWS systems to the remaining 13 states.

Given AFOS's present level of implementation, it has been possible to reduce the NWWS operations staff to 118, who are being cross-utilized to support other programs as well. Once AFOS is fully implemented nationally, the NWWS function will be eliminated entirely. The expansion of NWWS is proceeding as planned without additional positions. Thus, a total of 100 positions have already been saved and applied to AFOS, and the remaining position savings will be achieved as planned.

The additional freed positions have already been anticipated in implementing the NOAA Weather Radio program without new positions and in allocating personnel reductions the past few years. This has created an understaffing situation in the NWS that urgently needs correction, and AFOS provides the only know solution.

The communications savings are realized through the concentration of more information onto fewer circuits. Due to the anticipated delay in AFOS implementation, together with requirements for higher quality facsimile, we have discontinued two circuits (FOFAX and NAMFAX) in favor of a higher performance DIFAX system. In 1984, the savings will be realized from the removal of the facsimile and teletypewriter terminal equipment. We expect our original estimates ($2.6M) will hold up, although delayed somewhat in time.

Thus, while the value or cost avoidance picture may not match precisely what was anticipated in the PDP 5 years ago, they are quite similar. In fact, even at this preoperational stage, we are already realizing significant value from the AFOS system.

FUTURE SYSTEM

With regard to the development of a follow-on system to AFOS, the PDP prepared in 1976 recognized that the AFOS system was the beginning of an era in which data processing and display

technology would be used to enhance weather services by assisting the forecaster at the field office level of the Weather Service. Also, future needs and opportunities for improving weather services would arise requiring modifications and expansion of the original system. The GAO has not separated original requirements from future requirements and opportunities. For example, while the present AFOS system handles processed radar and satellite information, it is not capable of interactively integrating satellite and radar data nor was it intended to do so. Research in this regard is now being pursued in NOAA under the Prototype Regional Observing and Forecasting Service program approved in 1980 by the Congress. The earliest time an advanced capability of this type could be introduced in the field would be about 1990. To try it sooner would involve high risk and crash effort. Since the design of such a system is at a very early stage, no useful estimates of its cost can be made. The value attributed to the Director of the NWS, in the report, was not made in any numerical sense. He stated that the cost would be at least as great as that of the present system.

Potential Cost of AFOS 1982-1989

The GAO comparison of operating the Weather Service with and without AFOS throughout the 1980's is misleading and erroneous. In the GAO analysis, it was assumed that AFOS will have zero value to the Weather Service. The above discussion has shown that there is substantial value to be derived from AFOS in the preparation of warnings and forecasts and in their dissemination. In addition to the GAO analysis, the costs of operating AFOS are overstated by applying an overhead scheme which is different than the one used in NOAA. GAO also assumes that the FAA circuits will be available through 1989; when actually, FAA plans to remove the circuits with their modernization program.

CONCLUSIONS

NOAA does not agree with the conclusion that AFOS is 5 years behind schedule and $22M over budget. As pointed out in the above discussion of the AFOS schedule and costs, the AFOS program is 2 years behind the schedule set forth in the 1976 PDP with the operational date being end of FY 1982 when AFOS is the primary mode of operation at all equipped stations and not the latter date of September 1984 when the standby teletypewriter and facsimile communications are removed.

In arriving at the $22M overbudget conclusion, GAO misinterpreted by $9.4M the initial new budget authority and the total congressional authorization for AFOS through FY 1980. Also, GAO was inconsistant in not applying overhead costs to both plan and expenditures. When properly applied, NWS estimates the amount over budget to be of the order of $2M.

We do not agree with the estimated savings which GAO ascribes to maintaining the present system through 1989 versus using AFOS operationally while developing a new system for implementation at that time. GAO overstates the continuing cost of AFOS by including overhead, erroneously assumes FAA circuits will continue, and fails to attribute value to the interim operation of AFOS.

With reference to accounting for AFOS costs, the NWS has followed an approved organizational accounting system. Some of the staff effort should have been attributed as a direct cost to AFOS. This will be corrected.

NOAA does not agree that it has understated the future costs of AFOS. We contend that it is not appropriate to include overhead costs. The AFOS program has little impact on the basis for allocating such distributable costs.

RECOMMENDATION

The action recommended is not considered necessary. The NWS will, as it has in past, comply with Department of Commerce's accounting system and, therefore, intends to apply A-109 procedures.

CHAPTER 3

# MANAGEMENT OF AFOS

## Scope of AFOS Program Management

The introduction of AFOS into the National Weather Service substantially changes the way thousands of personnel do their work. The system is pervasive and directly affects almost every organizational unit across the country. The system is very different from the conventional centralized ADP facility staffed and operated by ADP professionals. It is a decentralized, distributed processing system in which the local processors serve as an intimate, interactive extension of the field forecasters at each field office. At the same time, the processors are integral elements of a unified telecommunications and information storage system that spans the entire country. These latter functions require strong, centralized operational control.

For these reasons, the management arrangements for AFOS have to consider much more than the development and testing of the hardware, software and support elements for the distributed processing system, even though that is an extremely large and complex task for which few if any precedents exist. The management arrangements also have to motivate and facilitate the transition to a totally different mode of operation for the majority of the NWS workforce, and also alter many significant relationships with other agencies and users. All this has to be accomplished witnout disruption to existing services and the activities of external users, concurrently with the expansion and improvement of service functions, and without any increase in NWS staffing levels. Further, it had to be accomplished within an organization having more than a century-long tradition in the previous mode of operation, with very limited prior exposure to computers and automation technology in the field force. Finally, as the program progressed through various development stages, problems were encountered that required management adjustments.

The institution and management arrangements must be responsive to the above situation. These arrangements have evolved during the course of the program in response to the changing emphasis needed at different stages, actual experience with the arrangements chosen, and recommendations made by consultants retained by NWS to assist in areas where special expertise was available. The management schemes adopted by NWS were innovative and deliberately departed in some ways from classical, text-book project structures because the needs of the program extended far beyond the classical problems those structures were devised to address. NWS management officials feel that the general thrust of GAO's criticism of NWS management reflects a distorted emphasis on classical

"engineering" system development as practiced in development organizations and a rather shallow appreciation of the real-world problems of development and change within a service organization conducting day-to-day, time-critical operations. The priorities necessarily must be different.

Nevertheless, NOAA recognizes the validity of most of the general management principles cited in the draft report, and a conscientious effort has been and is being made to apply them effectively in the management of AFOS. In fact, in the initial phases of the AFOS program the entire development - system analysis, hardware, software, and system experimentation and evaluation was organized under one single project manager reporting to the Office of the Director of NWS. The project manager was an experienced systems engineer. It was during this period that many of the decisions, repeatedly critized by GAO, on software, hardware and telecommunications were made. In other words purity of organization does not, as GAO implies, necessarily lead to success.

In hindsight, we recognize that some decisions, actions and inactions resulted in problems that were not forseen at the time and might have been avoided had another path been selected. In general, NOAA does not agree with GAO that a large fraction of the problems encountered in AFOS were caused mainly by the lack of coherent management, but rather by the sweeping scope and inherent complexity of the program. While a different management approach may have reduced or avoided some problems, it would have made other kinds of problems more likely.

Current AFOS Management Structure

NOAA believes that the NWS has learned much from the problems encountered (and the successes achieved). A much more mature program structure is now in place, and the technical knowledge needed to operate and sustain AFOS has been broadly established throughout the organization. The existence of past problems, whether attributable to management deficiencies or not, is not a rational basis for not using a system after the problems are resolved.

The current AFOS management structure explicitly addresses the current stage of transition of the initial system from development and testing into operational use. There is a single AFOS Program Manager, an SES member who reports directly to the Director of the NWS, and who has been delegated broad responsibility and authority for the program. In apparent contradiction to the draft GAO report, all staff responsible for development of AFOS report to him (many through intermediate supervisors). While this contradiction may result partially from adjustments made during the course of GAO's review, it may stem partly from confusion over the role of field personnel. As described in Chapter 2, AFOS includes a

powerful and versatile capability to support local applications concurrently with the telecommunications and other functions. The system capability for local applications has been developed and managed centrally. However, many of the specific computer programs (instructions) to carry out specific applications have been developed by field personnel with the full blessing and authorization of central management. Most of these applications are tailored to the needs of local service offices, and local managers have been delegated responsibility and authority for assigning priorities for use of the resources allocated to local processing within the overall AFOS system. Central management provides and enforces written guidelines and standards for local applications programs, and maintains a clearinghouse function for documentation and national exchange of applications programs.

The AFOS Program Manager has the authority to make decisions and establish policies which bind all organizational elements of NWS, including the field elements. Obviously, this must be done judiciously and with broad participation by managers of the affected elements to insure that continuing service operations are not disrupted. It is true that the Directors of the NWS field regions don't report to the AFOS Program Manager and are not formally rated by him, nor do the Director of the National Meteorological Center or the Directors of the other three National Headquarters Offices. Such an arrangement would be tantamount to redefining the Director of NWS. Nevertheless, for AFOS program matters the Director relies on the AFOS Manager and has directed the other senior managers to follow his leadership unless an irreconcilable conflict occurs that must be resolved by the Director. No problems of substance have occurred with this arrangement since it was instituted in March of 1980.

The implementation of the initial AFOS System has been assigned in a project sense to a single project manager under the AFOS Program Manager. All personnel involved in final development and testing, network monitoring and control, training, procedural development and documentation report to him as part of a Transition Task Team. The Team compromises a Development Task Group and an Operations Task Group, each headed by an SES member at the Laboratory and Division Director level. The Operations Task Group includes the entire, newly created AFOS Operations Division that will be responsible for continuing management of all aspects of AFOS' operations following the formal commissioning of AFOS. All managers in NWS field organization who are responsible for AFOS, down to the field station level, take direction on AFOS matters from the AFOS Operations Manager who heads the division.

The maintenance, logistics and facilities support for AFOS is integrated with all similar functions in NWS, both at the headquarters level in the Office of Technical Services where the overall programs are managed and in the field organization

where technicians for local sites and service areas are located. As AFOS becomes operational, a growing fraction of the effort in these programs shifts to support of AFOS. The AFOS Operations Manager also is formally designated Deputy Director of the Office of Technical Services, and therefore has actual line authority over the key operational elements supporting AFOS as part of nationally integrated support programs.

The AFOS Program Manager also has full responsibility and authority for future system development, and all staff involved in this effort report to him. He also serves as chairman of the formal AFOS Change Management Board at the Office Director level which is chartered by the Director, with broad delegation of authority, to establish all policies and mechanisms necessary to control and promote orderly improvements in the system and its operations. To date, mechanisms have been chartered and established by the Change Management Board for configuration control; addition, deletion and change in priority of AFOS products; and local applications development and exchange.

A plan has been developed under the leadership of the AFOS Program Manager for completing development and implementation of the initial AFOS system; introducing enhancements to the system (e.g., to equip with remote terminals the smaller NWS stations not planned to have stand-alone AFOS computers, and withdrawing temporary, backup teletypewriter and facsimile systems); and developing major system improvements that incorporate data types and functional capabilities never planned for the initial AFOS system. This plan covers the time period into the 1990's, with proportionally less specific technical and operational detail in distant years, but sufficient to define the overall strategy, guide budget and program development activities, and establish priorities.

NOAA believes that the existing AFOS management arrangements are well-conceived and they consider not only the points raised by GAO, but many other factors not even recognized by GAO, some of them much more important to the success of the AFOS Program. The NWS management personnel at all levels in the organization are no longer inexperienced in ADP system development and management, even if that were partially true at an earlier time. NOAA notes the success NWS has achieved in the difficult task of developing and introducing interactive,distributed processing technology into a service operations environment.

Comments on GAO Views

The specific comments on AFOS management by the GAO, unfortunately, contain misconceptions, over-simplication of cause and effect. We hope that the foregoing summary of the current AFOS management arrangements dispels most of the confusion and clearly distinguishes facts.

In particular, the current arrangement includes the key management principles that GAO claims we have not followed, e.g. management focus, clear lines of authority, sufficient authority, balance between centralized and decentralized authority, use of project managers and project management disciplines, and use of comprehensive plans.

It is difficult to answer the historical charges one by one without allocating many paragraphs. Suffice it to say that we consider it unlikely that the existing system could have been brought to the successful stage of development now achieved, if the program management were as lacking as claimed. NOAA admits that unforeseen problems did occur in the program, but they have been identified and corrected, and this success is a better measure of future expectations.

Contrary to the broad generalizations by GAO, NOAA applied appropriate approaches to managing large projects. Certainly, not all approaches were applied because some are alternatives to others. Similarly, concerning our use of contractors and consultants, not all recommendations were automatically accepted and implemented. NWS procured the entire hardware system through contractors, obtained major pieces of software through contractors, and obtained and applied a great deal of useful advice from contractors. The performance of the system validates these uses of contractors. It is illogical to argue that each and every recommendation of consultants should be followed in detail. In fact, it would be impossible because consultants don't always agree. No contractor has the breadth and completeness of knowledge about program issues that the agency possesses, and all recommendations must be evaluated by the agency in the light of all considerations. (For example, an unquoted corollary recommendation to one of those quoted in the GAO report, by the same consultant, suggested that we add immediately a dozen software experts in real-time systems analysis in order to complete a critical job in the succeeding few months, a desirable but totally impractical action.)

The GAO report repeatedly stresses the lack of experience of NWS with ADP system development, criticizes on page 23 the expertise of NWS managers, urges contracting out major ADP system development, and then finishes by asserting the concurrence of the Director of NWS with (an unspecified portion of) the GAO position. In truth, the Director of NWS does concur in the appropriate use of contractors. However, he reports having encountered far more problems resulting from ADP specialists who do not understand weather services and government procedures. The management staff must appreciate both weather services and systems development, and persons who are recognized among the top national experts in both disciplines are rare or non-existent.

CONCLUSIONS

Referring to the summary conclusions, we believe that GAO has exaggerated the influence of management deficiencies on AFOS development problems, and has failed to understand fully the reasons for the management approaches used. That not all problems were foreseen cannot be attributed primarily to management, but results largely from the complexity of the program and the difficulty everyone has in predicting the future. The only real criterion for evaluating management is the degree of success of the program, and the AFOS System successfully performs all essential functions and is used to support routine service operations even today. NWS now has a trained and experienced development team, operating force and management group. These accomplishments should be the basis for judging the accuracy and relevance of the GAO assertions.

RECOMMENDATIONS

The NWS already has implemented the specific GAO recommendations that are applicable to the existing system, and furture plans are in concurrence with those referring to the new system. In particular, the following actions have been taken:

1. An AFOS project management office has been established and all development personnel have been assigned to that office on a full-time basis.

2. A project manager has been appointed with clear authority for the project.

For development of the new system, NWS plans include:

3. Selection and enforcement of standard software development procedures, including documentation and testing for the new system, and

4. Contracting system development activities.

APPENDIX II

## CHAPTER 4

## AFOS SOFTWARE

### Software Capability

Advances in the science of meteorology over the years have been substantial. Forecasters today have enhanced analytical techniques, computer models, and computer-generated guidance to aid them in the formulation of their products and forecasts. But, forecasts are still in part the result of the individualized application of experience, the complex assimilation of current and historical weather information, and in some instances the "gut feeling" of the forecaster. This variability in procedure coupled with a workforce generally unfamiliar with automation technologies impeded the development of, and agreement on, detailed requirements in areas where personnel interact with the system. On the other hand, many system software requirements were originally specified in the design stages of the AFOS program (mid-1970's) and have remained throughout.

Originally the AFOS software development involved designers and users in an iterative design, test, evaluate, and modify process that attempted to capture and define the more subtle software requirements. AFOS software development began in the mid-1970's and was scheduled to take place over the time frame of several years and not the 90 days the GAO contends. This form of development, if properly managed and controlled, often yields the most satisfactory systems performance. As the GAO points out, the NWS did encounter difficulties managing this phase of the software development which affected the overall software development timetable. But this process yielded a system whose functional performance and capabilities could be effectively used by field personnel and one which has been widely accepted throughout the NWS.

AFOS software meets the original objectives as listed in the AFOS Program Development Plan and subsequently determined by interaction with operational personnel. As described in detail in Chapter 2, AFOS receives information from the telecommunications subsystem and stores it for subsequent use by the forecasters; the system retrieves stored information for display in various useful ways; and it facilitates the composition and automatic transmission of messages and carries out many meteorological and hydrological applications and services. The AFOS software now in actual field use accomplishes these essential tasks reliably, rapidly, and makes effective use of the computer, telecommunications resources, and other system features.

Software Development

A point that cannot be overstated is that AFOS is a complex system. AFOS software is also complex and, as the GAO states, is tightly integrated. While the tightly coupled or integrated software is a problem to those who must design subsequent changes in AFOS, it does not affect the operational user. Even though the software performance is entirely satisfactory, NWS intends to make a few structural changes to the software to facilitate improvements as operational experience is gained. These changes would also incorporate additional computer memory.

The NWS has demonstrated effective software development management practices. For example, in April 1980 the entire asychronous communication subsystem, representing an additional one-third of the real-time computer code, was successfully integrated into the existing software, debugged, and tested. This fact directly contradicts the GAO contention that "from 1978 to the present the developers have been reducing system capability in an effort to achieve a stable system"--an unsupported and false allegation. The GAO report lists other software problems such as: the communications subsystem does not perform acceptably, more than one forecaster cannot use the system at a time, only one software back-up routine works reliably and message composition failures cause the loss of prepared messages. Currently the AFOS software permits the satisfactory use of all consoles at each field site (the largest station has 8 consoles), and message composition recovery is fully operable and prevents the loss of text. The system back-up capabilities as described in Chapter 2 are tested and in use today, and the AFOS telecommunication system functions satisfactorily as described in Chapter 5.

In mid-1979 NWS management determined that the developers were having technical difficulty in completing development and tests of the system and there was a need to strengthen overall program management. The new program management immediately instituted classically accepted development and testing disciplines. An interim software change management process was invoked and utilized until the spring of 1981 when the NWS formally instituted an AFOS Change Management Board with a specific charter and delegations of responsibility and authority from the Director, NWS.

Prior to mid-1979 software was insufficiently documented, but GAO's strong criticism of documentation is not valid now. Hardware documentation was fully established by the AFOS hardware contractor. An initial level of software documentation was established by an intense 5-month effort of the entire software development staff. In 1980, the NWS contracted with a private contractor to develop a formal set of software documentation. This documentation, containing more than 8,000 pages in 14 separate bound volumes, will start being delivered to NWS in September 1981.

Software Test Program

The AFOS test program was re-established on a more firm technical base and systematically followed. Exactly how to accomplish this resulted from extensive deliberations internally and with private consultants. The general consensus was that the capabilities and functional performance of the system had evolved to a satisfactory level, but system stability was inadequate. A path was chosen that made maximum use of the iterative development process described earlier. To the developers this was translated to the following conclusions: the fundamental algorithms and processes being performed by the software modules were satisfactory; the interactions of the software modules alone and in aggregate numbers were most probably the cause of system instability; lesser software defects or "bugs" would be uncovered and corrected.

A highly specialized test methodology was then designed and implemented. A test structure was laid over the existing system which provided accountability and intermediate goals. A test management structure was implemented at that time using individuals who had no previous investment in the development process. This plan of attack was reviewed and endorsed by a private contractor.

The test program initiated in early 1980, while not fully ortnodox in its design, was well considered and has been successful. At that time system stability was relatively poor with stations experiencing system interruptions almost hourly which required 6 to 10 minutes to correct. The stability currently being reported by the field stations is less than one interruption per shift and requiring only 2 to 5 minutes to correct. This is a fully acceptable level for operational use as demonstrated by the ability of two of the four contiguous regions to use AFOS as the primary tool for the delivery of weather services.

CONCLUSIONS

NOAA does not agree with the GAO conclusions that software developed for AFOS has serious problems which can only be resolved by a complete redesign. A systematic NWS test program has validated the software design. The current actual use of the AFOS software in day-to-day field operations demonstrates satisfactory performance. The NWS is planning to make some limited improvements to the software in the future. We intend to make appropriate use of contractors for this effort.

RECOMMENDATION

NOAA does not agree with the recommendation to redevelop AFOS software as part of a complete redesign and redevelopment. The existing software meets all essential requirements for field use.

APPENDIX II

CHAPTER 5

## AFOS TELECOMMUNICATIONS

### AFOS Telecommunication Design

For decades the NWS has been using multiple low speed teletype and facsimile circuits to deliver all of the alpha-numeric and graphic information the forecaster needs to generate forecast products. A single AFOS telecommunication system is able to transmit all of these different alpha-numeric and graphic products reliably enough for forecasters to continue to provide warning and other weather services to the public. In addition, AFOS has demonstrated improvement to other aspects of NWS operations. AFOS provides warnings and other service products to the public and other users via NWWS. NOAA does not intend to provide basic meteorological data and information to private users and other meteorologists on AFOS, but will provide separate communication facilities for this purpose.

AFOS communication speeds are an order of magnitude faster than existing teletype speeds thus permitting the reliable delivery of weather information at significantly earlier times. This affords forecasters valuable additional time to analyze and prepare warning messages. The AFOS system automatically transmits, stores, and updates a site's local data base without human intervention thus achieving even greater productivity of NWS personnel.

Contrary to the GAO interpretation, AFOS communication circuits are aligned with the decentralized organization of the NWS. Each Regional Distribution Circuit (RDC) is supplied the same meteorological data by the System Monitoring and Coordination Center (SMCC) in Suitland, Maryland. All Weather Service forecast offices (WSFO's) within a Region, are connected on their own RDC. Each forecast office has associated with it a number of Weather Service Offices (WSO'S) that are interconnected directly to WSFO's by State Distribution Circuits (SDC) which is in alignment with the area forecast management structure within a state.

The data and information flowing into and out of the AFOS System is part of the world wide interchange of weather information that takes place at the National Meteorological Center (NMC) in Suitland, Maryland. The NWS has operated this communication hub reliably for decades.

The selection of the AFOS communications loop architecture was the result of extensive analysis by the NWS, private companies, and the National Bureau of Standards in the mid-1970's. A communication network did not exist that suited AFOS' purpose. As the AFOS communication system has been implemented and tested, numerous improvements have evolved that have increased overall performance and reliability. The testing

has been performed largely by the NWS, but a private contractor was assigned to review, test, and evaluate the system also.

Reliability

All AFOS communication circuits are installed and operating. Presently the SMCC is in its final configuration, having recently completed a series of engineering and validation tests. Each RDC is being driven from its assigned SMCC computers. SMCC operations are meeting service requirements for reliability and timeliness of data flow

As the evolution of the telecommunication system reached the levels of reliability and stability the NWS needs, the RDC's were implemented starting in 1980, and each region began the process of transition to full AFOS operations. Since that time the stability and reliability of AFOS telecommunication has continued to improve as management and operational procedures have been developed and refined.

The reliability of AFOS communications depends on several factors, the principal ones being the dedicated telephone links connecting each node (WSFO), secondly the sites' computer controlled and managed synchronous communication subsystem, and thirdly the various backup modes designed into the system. All these components have been tested separately and as an integrated system. The performance of the entire system in actual operations under all types of environmental conditions is satisfactory for NWS operational use.

The telecommunication system back-up modes incorporate the following automatic and operator initiated processes: (1) the AFOS communication computers use an industry accepted communication protocol that incorporates automatic error detection and retransmission features. (2) Data is routed bi-directionally around each RDC thus ensuring that should a particular node or telephone line fail, all other nodes receive data. (3) In the event that the connecting link between adjacent nodes fails the communication computers automatically reconnect with each other using standard dial-up circuits. (4) Should a node experience a catastrophic failure, the computers at adjacent AFOS nodes can be directed by station personnel to "dial around" the failed node. (5) As described in Chapter 2 either of the two computers located at a node can perform all telecommunication functions thus providing an additional level of back up. (6) the telecommunication subsystem for either computer has back-up equipment also. All back-up modes have been extensively tested and perform satisfactorily. In contrast to this level of sophistication, the teletypewriter circuits used today, which are also loop networks, contain none of these back-up features. If a teletypewriter loop is broken, communications cease.

A significant disagreement exists between the NWS and GAO on the level of support required for telecommunication. Given the overall current high level of stability of the AFOS hardware, software, and communication lines, the amount of operator intervention or attention to maintain systems operation is currently reported at less than 5 minutes per 8 hour shift. This is significantly less than the time required to service the multiple teletypewriter and facsimile equipment at each site. It is also significantly less time than that which the GAO observed as late as January of this year.

As described earlier, the SMCC plays a vital role in AFOS communication. It must interface with NMC and simultaneously drive the four RDC's. In addition, SMCC monitors the status of the RDC's, notifies station personnel of malfunctions, and advises them on the corrective action to be taken. At the point in time when the GAO inspected SMCC it had neither been reconfigured to drive four RDC's nor had it undergone the planned engineering and validation tests scheduled for it. Hence the GAO's pessimistic view on the adequacy of SMCC is understandable. Since March of this year however, scheduled tests have been conducted that verified the performance and reliability of the SMCC computers. The stability of the SMCC systems is now extremely high. Defects uncovered during testing have been corrected and retested. The SMCC is driving the four RDC's with live meteorological data from the National Meteorological Center.

In January of this year, the NWS conducted a major engineering test of the AFOS system on a test network that interconnected several sites in each region. Station personnel were instructed to use their AFOS systems to the degree their training and experience permitted. This was a test of the AFOS system in a near-operational setting under the random variables of environment, nationwide communication, and operator interaction. It was not a test of NWS service operation using AFOS. Perhaps the NWS did not adequately explain the purpose of these tests, nonetheless the GAO has incorrectly drawn conclusions from NWS test briefings and reports concerning the suitability of the AFOS system to perform satisfactorily in operational use. There were only two significant engineering defects discovered during the Systems Operations Test. One had to do with delayed transmissions from NMC to SMCC, the other, the presence of unnecessary traffic on the test loop. The latter problem was easily corrected and retested. The other defect has been corrected as part of the NMC-SMCC validation tests.

Telecommunication Alternatives

The NWS has been examining the current status of the telecommunication technologies. Apparently the GAO has interpreted this effort as a signal that the NWS did not believe the design of the AFOS telecommunication system to be viable. The NWS has been using private contractors for the past year to assess the current state of telecommunications technology from two viewpoints: first to identify an alternative system that could be implemented should testing reveal AFOS communication to be unreliable and, second, to identify trends in the telecommunication technology in anticipation of the development of the next generation system. The former was a programmatic plan to ensure continuous implementation of AFOS; however, this study reveals there is no off-the-shelf system to replace the AFOS communication systems economically. The latter is a continuation of the NWS practice of conducting periodic technology assessments. We feel these are prudent and responsible programmatic and agency planning activities.

CONCLUSIONS:

The GAO argues that AFOS telecommunication is not appropriate for meeting NWS needs, is inflexible, unreliable, and conflicts with the NWS organizational philosophy. NOAA cannot agree with these conclusions and has demonstrated, by both engineering tests and actual operational use, satisfactory and reliable performance of the telecommunication system in both its normal and backup modes. The NWS agrees with GAO that AFOS communication is the least costly of other possible designs. The NWS concludes that the low cost of AFOS communication coupled with the proven satisfactory performance yields a truly cost-effective telecommunication system.

RECOMMENDATION

NOAA does not agree with the GAO recommendation that the AFOS telecommunciation system be replaced with an as yet undefined and unproven alternative system. The present AFOS system is performing satisfactorily and any effort to replace it now would unnecessarily delay implementation of AFOS, add significant unnecessary cost and prevent the NWS from utilizing a very important and effective tool in the discharge of its public service responsibility.

## CHAPTER 6

## AFOS HARDWARE

### Current Status

The AFOS hardware consists of minicomputers, display consoles, printers, magnetic discs, and telecommunication equipment. This equipment was competitively procured against a technical specification prepared by the NWS. The hardware specification established requirements for system functional capabilities, maintainability, and reliability. This procurement also required the contractor to perform analysis and specify logistic levels and geographical distributions that would ensure satisfactory and reliable hardware maintenance. In addition, the contractor was to provide NWS specified computerized automatic test equipment and the necessary computer diagnostic programs to be used in the AFOS repair depot in Kansas City, MO.

Acceptance of the hardware systems was based on a contractor generated and government approved test program that addressed systems performance, reliability, and maintainability. Performance tests examined each required capability of the system while the hardware was subjected to specified extremes of electrical power and ambient temperatures and humidity. Hardware reliability tests for AFOS are basically equipment endurance tests conducted over a statistically significant period of time based on Mil-Spec reliability test procedures. The equipment maintainability tests were established by the contractor and performed by NWS electronic technicians. These tests demonstrated that NWS factory trained technicians using contractor provided maintenance manuals, specified test equipment, and diagnostic aids were capable of restoring equipment operations within specified times.

The AFOS equipment passed all required tests for performance, reliability, and maintainability. All other contracted deliverables were similiarily accepted based upon approved test or inspection plans.

The AFOS hardware installation began in 1978 and was completed in 1981. As each system was installed NWS maintenance and logistic reporting programs were initiated to monitor and analyze significant aspects of the hardware's reliability, maintenance and performance throughout its lifetime. The equipment is expected to meet the initial contract acceptance criteria throughout its use, and system maintenance costs to remain within planned levels.

APPENDIX II

AFOS Logistics System

The AFOS logistics system has effectively supported AFOS operations for some time now. It includes approximately 10,000 Lowest Repairable Units (LRU's) i.e., repairable sub-assemblies and parts and about 30,000 non-repairable parts that support approximately 45,000 LRU's in daily use at all AFOS sites. (The number of non-repairable parts in daily use exceeds one million.) Contractor guaranteed-mean-time between failures projected approximately 7,000 LRU failures per year. Currently NWS is recording actual failures rate of about 3,000 per year. The problems with the flow and availability of spare parts have been resolved. AFOS maintenance and logistics programs have gone through exhaustive and repeated evaluation by NWS and are more than adequate to support AFOS operations. The AFOS maintenance and logistic management and support activities are in the forefront of technology and are effective in the operational support of the AFOS program.

The AFOS equipment since installation began, continues to meet and in most instances exceed specifications for performance, reliability, and maintainability. The original estimates of the need for 65 additional maintenance technicians made in the mid-1970's are still valid today. Of course the technician salaries have increased substantially. The original projections on the number of spare parts are still valid, but inflation has increased the cost of spare parts.

Contrary to the position of the GAO, the NWS has through experience established effective policies that determine whether or not to maintain its varied equipment systems at current manufacturers' equipment revision levels. Many of the manufacturers' revisions are intended to reduce manufacturing costs or modify certain performance characteristics and not necessarily correct specific problems. The NWS closely monitors AFOS vendor revisions and has selectively incorporated revisions to correct specific problems. In most instances these problems were identified during procurement acceptance tests or contract warranty periods. The costs to correct them are normally borne by the AFOS contractor.

A point of confusion in the GAO's argument is that hardware and software improvements made by the minicomputer manufacturer cannot be incorporated into the system without considerable cost and effort. It has been the practice of the computer trade in general, and the manufacturers of AFOS equipment in particular, to ensure that any manufacturing hardware revisions are fully compatible with its original system in form, fit, and function. This means that one need not incorporate every previous revision in order to take advantage of a later one that may correct a specific defect.

Modifications have been installed either by the contractor to correct latent defects or by the NWS to modify performance characteristics. Equipment modification is a routine type of activity in all maintenance programs. NWS has considerable experience in the area of equipment maintenance and modification since it maintains more than 7000 pieces of equipment that support meteorological and hydrological service functions. The NWS has demonstrated repeatedly that AFOS can be modified efficiently, effectively, and at reasonable cost, and based on its experience expects that this will remain the case for many more years. Why GAO argues that AFOS equipment does not meet NWS requirements, has limited capacity, and is expensive to repair in light of the actual maintenance record is puzzling.

AFOS Operating System

The GAO contends that the computer's operating system is inadequate, unsuitable for the purpose intended, and must be replaced. The AFOS computers' operating system is software written by the computer manufacturer. Computer operating systems being sold today are intended to serve the widest possible spectrum of customer needs. In developing their operating systems, vendors trade off between highly specialized and efficient software systems for more generalized, and in many instances, less efficient capabilities that serve a wider market and thus yield a greater return on investment. The AFOS operating system is similiar to others on the market in this respect. The NWS has modified the AFOS operating system to enhance its efficiency and data-handling capability in response to specific NWS requirements with a resultant improvement of the performance of the operating system.

The computer's operating system oversees and manages most of the functions of the computer. Within the architecture of this operating system, a user generates and operates his own computer programs suited to his specific requirements and in accordance with the rules and constraints of the operating system. The AFOS programs contain more than 500,000 lines of computer code that satisfy complex requirements and perform sophisticated functions as discussed in Chapter 4.

The operating system satisfies the basic requirements of the AFOS program. Naturally with its considerable experience in using the AFOS operating system, i.e., hindsight, it's possible for the NWS to speculate on how an improved operating system might be developed, but there are no operating systems on the market today specifically designed to satisfy AFOS requirements. The NWS did attempt to obtain, in the initial hardware contract, an operating system built specifically for AFOS needs. This path had to be abandoned in 1976 because the company could not build and deliver this hardware on the time schedule prescribed in the contract. The NWS has chosen the most reasonable path

available to it by acquiring an off-the-shelf operating system that had proven performance and then specifically tailoring it to the needs of the AFOS program.

Hardware Capacity

In light of its repeated and extensive tests of the performance of the system, the NWS does not agree with the GAO's comments on insufficient hardware capacity. The system does the job originally intended. That is not to say that the NWS cannot improve the performance or capability of the system. It can and is prepared to do so in the future.

As described in Chapter 2 of these comments, the AFOS system's back-up and recovery capability is in place and is satisfactorily performing in actual field use. System backups occur on multiple levels; each with its own specific limitation on performance of the system. Not surprisingly, practical experience with the back-up modes of AFOS has identified areas to strengthen. The NWS intends to do so in the future.

Hardware Replacement

Contrary to the assertion of the GAO, the AFOS system was not intended to satisfy all future requirements of the NWS. This is in accordance with the Federal ADP procurement policies. In general, new generations of computer systems have been introduced every 5 to 7 years that prove to be more efficient and effective with greater capabilities and at a lesser cost than previous ones. The presence of improved generations of equipment in itself is insufficient reason to replace systems if they are still economically supportable and effective tools in support of NWS operations.

NWS policy in regard to acquisition of equipment systems incorporates accepted principles of economic life planning. Each system is intended to satisfy a specific set of agency requirements and not be so generalized (and more costly and less effective) as to satisfy new and different changing requirements over the years. This appears to be a point of philosophical disagreement with the GAO. As new requirements are developed the NWS attempts to utilize the latest technologies to satisfy them. Supporting systems maintenance programs are designed to provide cost effective and highly reliable systems performance and availability. Subsequent equipment replacement programs are generated as a result of closely managing the costs and effectiveness of systems maintenance and NWS operation requirements.

CONCLUSIONS

NOAA does not agree with the GAO conclusion that the design and capability of the AFOS hardware and operating system are inadequate. The AFOS hardware has successfully passed repeated tests and evaluations and the test of operational use. It is satisfactory for AFOS operations. The AFOS computer's operating system has been tailored to the specific application of AFOS required for successful AFOS performance.

RECOMMENDATIONS

NOAA objects to the GAO recommendation that AFOS hardware be replaced as part of a complete system redesign. It's NOAA's position that to replace satisfactory operational equipment and discard a massive logistic and repair system capable of meeting essential NWS requirements for support of AFOS operations is not responsible use of public funds and human resources.

APPENDIX II

## CHAPTER 7

## FUTURE OF AFOS

The GAO recommends that further development and use of AFOS be abandoned; that resources be redirected to planning and developing a new system to replace AFOS and the current system; and that NWS should rely solely on pre-AFOS communication systems until the new system is developed. NOAA believes that the existing AFOS system should be implemented nationally during FY 1982 as the primary weather information system supporting NWS field observations; that pre-AFOS communications be used as a backup to the AFOS communications subsystem, and to support field offices not equipped with AFOS, until the end of FY 1984; and that a next generation system incorporating advanced capabilities never intended for the initial AFOS system should be developed for implementation by the end of the decade.

The GAO recommendations propose a radical departure from the plans developed and substantially fulfilled by AFOS after a major investment of talent and at least $90M over a period of seven years. The payoff from this investment would be essentially lost. NOAA believes that GAO must assume a heavy burden of justification for such a drastic action. The preceding chapters of these comments have systematically shown that the basic conclusions supporting this recommendation do not correspond with current observable facts, are logically inadequate and incomplete, and involve inappropriate and incorrect judgments about the requirements of the NWS and the value of AFOS to NWS operations. Further, NOAA objects to numerous misattributions to the NWS and its Director, especially in Chapter 7 of the draft GAO report, in the form both of inaccurate paraphasing and selective attributions seriously out of context.

In order to provide coherent and systematic comments, NOAA has not responded in each case to repetitious statements and arguments in the GAO report with which NOAA disagrees. The absence of an explicit rejection by NOAA of a particular sentence or paragraph must not be taken as tacit acceptance by NOAA. However, to assist in sharpening the contrast in NOAA's and GAO's assessments and their respective foundations, we have attempted to assemble a more concise and less redundant comparison in this section. We recognize that this may result in some loss of immediate context of GAO's arguments, but we have made an honest attempt to reflect them accurately, and the full text of the GAO report is there to preserve the original context.

The following conclusions stated explicitly by GAO (often with more or different words) seem to form the central foundation of the GAO's main recommendations:

1. AFOS has major problems in its software, hardware and telecommunications.

2. AFOS is not sufficiently stable and reliable to use as a primary system.

3. AFOS has inadequate backup capabilities, and the most critical ones in the original design have been eliminated.

4. Improvement of AFOS is risky, costly and impractical due to fundamental design flaws.

5. AFOS is too expensive to operate and maintain.

6. AFOS capabilities do not meet original requirements, and a complete redesign and redevelopment is necessary to meet them.

7. AFOS cannot meet future requirements.

8. The value of AFOS is negligible.

9. Not operating AFOS would save $116M over the next 8 years.

10. The only costs associated with reverting to pre-AFOS operations is the current cost of using FAA's teletypewriter circuits.

11. NWS can operate satisfactorily and meet service requirements for the rest of the decade without AFOS.

12. NWS has insufficient staff and capability to both operate and maintain AFOS, and plan and develop an advanced system.

In addition, some key implicit assumptions underlying GAO's recommendations need to be considered:

13. The resources previously available for AFOS can be diverted to developing a new system, would be sufficient for the new system, and be available in the required time phasing.

14. A new system and its development would not encounter technical, cost, schedule or transitional problems as serious as those of AFOS, provided recommended management procedures are used and development is done by contractors.

In contrast, the corresponding points of NOAA's assessment are summarized as follows:

1. No major problems in AFOS software, hardware, or telecommunications remain that affect its essential functional capabilities.

2. AFOS is sufficiently stable and reliable to use as the primary system; the existing AFOS system is now serving as the primary system in two of the four contiguous NWS regions; and operational adequacy will be demonstrated during August and September 1981.

3. The most important backup capabilities designed into AFOS have been implemented, and the pre-AFOS communications arrangements will be retained as an added backup through FY 1984.

4. Improvements in AFOS have been incorporated successfully during the last year, and NWS believes that some investment in selective improvements (not fundamental redesign and development), retaining the existing hardware and most of the software, will further improve system performance and facilitate future software maintenance and enhancement.

5. The cost of operating and maintaining AFOS is close to the projections made in 1976 when adjusted for the effects of inflation on salaries and spare parts.

6. The existing AFOS system meets all significant original requirements except for early withdrawal of teletypewriter and facsimile capabilities, retained as backup, and substantially exceeds original expections in some areas such as forecaster assistance.

7. The initial AFOS system was never intended or designed to meet all future requirements, and particularly not those cited by GAO.

8. AFOS is extremely valuable to NWS operations; it significantly speeds up warnings and forecasts as planned, saves large numbers of staff-hours annually through automation of routine tasks, liberates time and resources for service improvements, and establishes a mode of operation amenable to future improvements.

9. GAO's estimate that $116M could be saved by not operating AFOS for 8 years does not consider important costs of trying to turn back to operations without AFOS, and totally ignores the major capabilities and efficiencies that would be lost.

10. Reverting to pre-AFOS systems involves much more than retaining connection to FAA's teletypewriter circuits, including refurbishing or replacing aging equipment of various types, substantially increasing field personnel, and making other potentially expensive adjustments.

11. Even current services could not be maintained using pre-AFOS systems without a major investment and upheaval in NWS, if at all. The pre-AFOS systems do not meet even 1974 NWS requirements; that is why the AFOS program was initiated to provide many capabilities not included at all in the previous systems.

12. Totally different kinds of personnel are involved in operating AFOS and in developing a new system; NWS can accomplish both concurrently.

13. The cost of a new system meeting all present and future requirements recommended by GAO is unknown, and GAO's estimate of $125 to $150 million is not based on any substantive analysis or knowledge of the requirements; and the assumption that more than $100M, now planned for expenditure in small pieces over eight years, can be gathered up for a procurement is at best doubtful.

14. The development of large, complex systems that break frontiers should be expected to encounter some problems; NOAA's experience shows that proceeding in a series of ambitious but prudent steps results in fewer problems than making a single giant leap to a new system incorporating even more novel features than AFOS, as proposed by GAO.

As indicated by the length and detail of these comments, there are many conclusions by the GAO that directly contradict NOAA's assessment. Much of the contradiction on those aspects related to system performance could be explained by the fact that GAO auditors made their observations of the system during an earlier period when development and testing were in progress, and many technical problems were evident. We can only assume that these difficulties appeared more fundamental and fatal to the auditors than proved to be the case.

We are troubled by the analysis of the alternatives involved in GAO's recommendation to abandon AFOS. The simplistic assertion that $116M can be saved over the next eight years by terminating AFOS is made without a thoughtful consideration of the relative costs, advantages and disadvantages of operation with and without AFOS. That the sole cost of operations without AFOS is considered by GAO to be NWS' cost of using the FAA's teletypewriter circuits (see table on page 14), while the comparative cost of operating AFOS includes all maintenance and support personnel, facilities, logistics, communications documentation and even millions of dollars of NOAA overhead, is not logical. That the difference in the functional capabilities of AFOS and teletypewriters were ignored is almost incredible.

The preceding sections of these comments present the bases for NOAA's disagreements with GAO's conclusions and recommendations. These bases are qualitatively different from those used by GAO. NOAA bases its conclusions upon thorough, up-to-date, first-hand experience in testing and using AFOS in support of weather service operations; upon deep understanding of the requirements the system must satisfy and their relative importance and urgency to weather service operations; and upon its knowledge of the importance of various current and needed weather services derived from more than a century of working directly with NWS users.

(061090)


DAT
ILM